State Policies for Geothermal Development

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Executive Director: Earl S. Mackey

State Policies for Geothermal Development

Uncovering a Major Resource

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Foreword

The Renewable Energy Resources Project was established in the spring of 1975 to help states define policies suited to the development of new energy sources, especially solar energy and geothermal resources. The project's final report concerning geothermal resources is presented here as *State Policies for Geothermal Development*. This report has been the work principally of Douglas Sacarto, with the assistance of Dena Bellows. The project as a whole has been directed by Patrick Binns, and was made possible through financial support from the National Science Foundation's Division of Intergovernmental Science and Public Technology.

State Policies for Geothermal Development reviews for the states various technical, economic and institutional aspects of geothermal development. The report summarizes research results from numerous specialists and outlines present state and federal policies affecting the geothermal industry. From this material key policy areas have been identified and several specific actions suggested for the states. The report concludes generally that if public policies are made favorable to their development, geothermal resources offer an important domestic energy supply.

The purpose of this report is to provide ideas to interested legislators and legislative staff for enhancing the development of geothermal resources. The report's numerous policy suggestions have not been considered for formal NCSL adoption, however, and they do not at this time represent an official NCSL position.

Earl S. Mackey
Executive Director
Denver, Colo.
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State Policies for Geothermal Development is built largely from the conclusions of other researchers. Any distortions of presentation, errors of interpretation, or opinions expressed in the report are, however, solely this author's responsibility.

1

Summary And Recommendations

THE VALUE OF GEOTHERMAL RESOURCES

Every point of the globe rests on an ocean of molten rock at 1000°C. Heat from this immense reservoir flows steadily to the earth's surface, where it appears most dramatically as volcanoes, hot springs and geysers. But valuable geothermal resources are more widespread than these special displays. Broad geothermal belts encircle the entire planet — including all of the western United States. In these areas, the earth's heat is accessible and forms a valuable, multifaceted resource. (Fig. 1)

Over the centuries numerous beneficial uses have been discovered for geothermal resources. Hot springs have traditionally been gathering places for recreation, and during the thirteenth century, the Larderello hot springs of Italy provided sulphur and other minerals for trade. Later, boric acid was commercially produced, and in 1904 electricity was first generated from the earth's heat, again at Larderello.[1]

With improvements in exploration, well drilling and electric conversion technology, geothermal resources have become available during the past decades on a broad scale. The growing demand for secure energy supplies has also made their development especially desirable. As a source of electricity, geothermal resources globally supply approximately 1500 megawatts (MW) of power from over a dozen geothermal areas. The Geysers dry-steam field north of San Francisco (the only commercial power development in the U.S.) generates about 500 MW, which is adequate to supply a city of one-half million. Equally important globally are direct heat uses for geothermal resources in agriculture, industrial processing and for heating and cooling of buildings. The Soviet Union, Hungary, Iceland and New Zealand far exceed other countries in direct application of geothermal energy; their use totals almost 6000 MW. In the United States, geothermal energy is used directly for heating at Klamath Falls, Oregon; Boise, Idaho; and in other scattered locations. (Fig. 2)

Present Potential

The energy potential of geothermal resources in the United States is hundreds of times greater than current use. Geothermal reserves in the western states, assessed by the U.S. Geological Survey, are adequate to supply all new electric capacity in those states for the next two decades. This energy — over 100,000 MW* — can be generated from natural steam and high-temperature geothermal fluids at prices competitive with electricity from fossil and nuclear powerplants.

Geothermal resources can also help limit new electric power demands and reduce our consumption of fossil fuels. Heating requirements (at temperatures typical of geothermal formations) in agriculture, industrial processing and for heating and cooling of buildings consume 60% of this nation's non-transportation fuels. Natural gas, oil, coal and electric power presently supply the energy. These limited fuels could instead be conserved through direct use of the earth's heat.

The Future

With vigorous development, geothermal resources could supply the United States with 5-10% of its electrical energy in the year 2000. In subsequent years, geothermal resources potentially could provide an even larger percentage of U.S. energy needs. New field discoveries should expand known high-temperature reserves; and the development of technology to exploit hot dry rock, intermediate-temperature systems, near-surface magma chambers and deep geothermal resources could make available a major long-term energy supply, possibly exceeding the nation's total energy requirements.[2]

Safe Energy

In addition to their energy potential, geothermal power projects are environmentally safe compared to coal combustion and nuclear fission. Geothermal resources can be produced and wastes disposed through wells with limited disturbance to the land, to ground and surface waters or to other natural resources. In contrast, surface mining of coal and uranium disrupts large land areas and wildlife habitats, and produces extensive water and air pollution.

Geothermal powerplants also are relatively clean. They create no major pollutants comparable in quantity

*Total U.S. electric capacity from all sources is now approximately 500,000 MW.

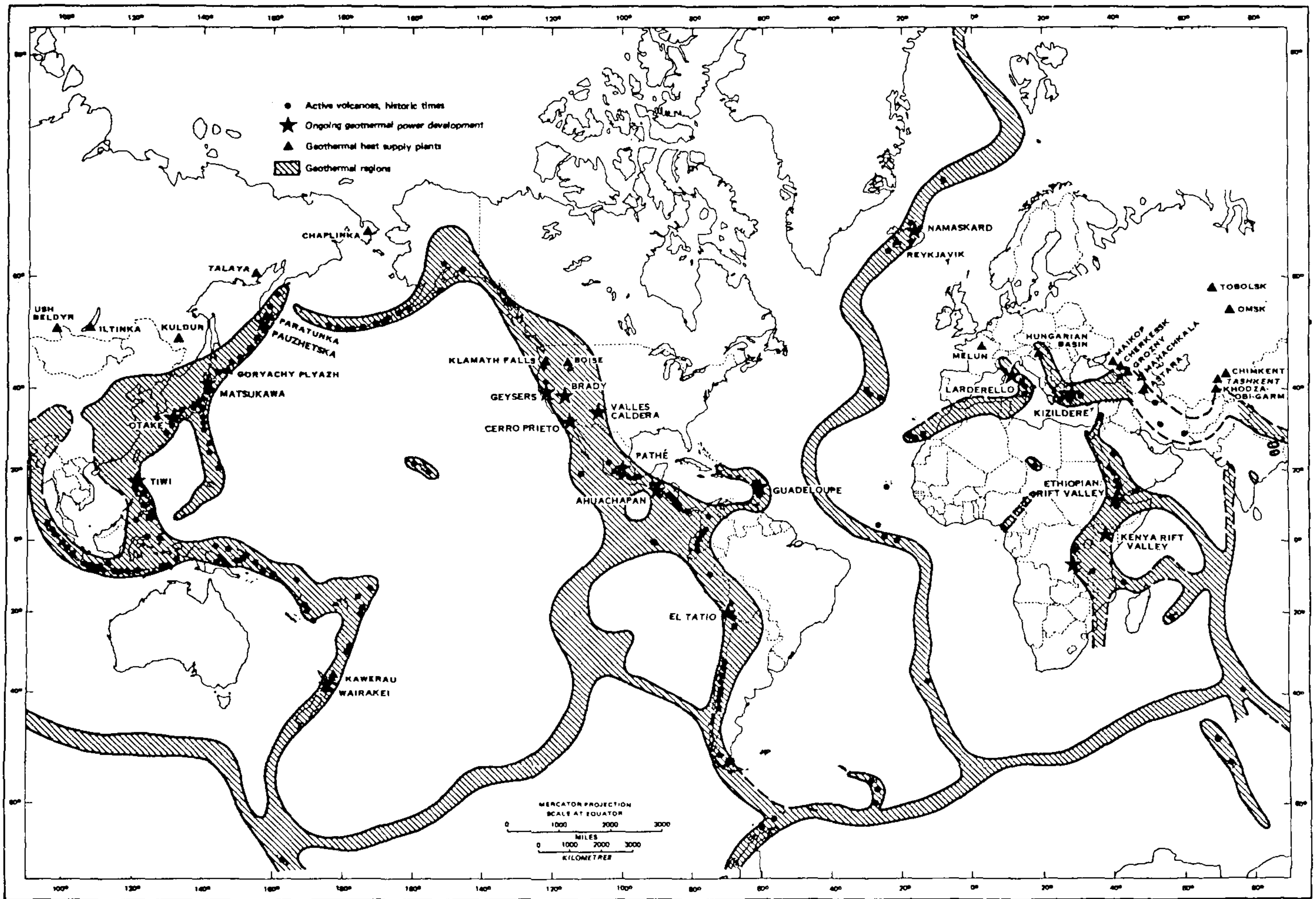

Fig. 1. Geothermal regions of the world (courtesy of Tsvi Meidav, Geonomics Inc.)

or complexity to air pollution from coal-fired plants (SO_x,NO_x, particulates) or to radioactive wastes from fission reactors.

At all stages, therefore, geothermal development offers a secure domestic energy supply with comparatively minor environmental impacts. And other land uses, such as farming, are not excluded by geothermal facilities. At The Geysers, cattle grazing and recreational hunting continue in the area of geothermal operations; and large-scale geothermal development has for several decades been compatible with vineyards, orchards and seed crop farming in the Larderello district of Italy.[3]

OBSTACLES TO GEOTHERMAL DEVELOPMENT

To develop the assessed potential of geothermal resources within the next twenty years, investment must expand greatly beyond its present level. Over $75 billion at today's costs will be needed to discover and produce 100,000 MW of electric power from geothermal resources. Approximately 65,000 wells will need to be drilled. At the present rate of development, however, this goal will not be reached for several centuries.

A number of conditions hinder rapid development of geothermal resources. Electric utilities—the primary purchaser of geothermal resources for electric generation—are wary of new, unfamiliar energy sources. At present, utilities have scheduled no large-scale geothermal plant construction outside The Geysers area of California. Their hesitancy is increased by the fact that geothermal generating facilities must rely on a single reservoir. With only limited experience, the long-term reliability of geothermal reservoirs is still uncertain. Utility confidence will be necessary, however, for widespread geothermal development.

The reluctance of consumers to rely on geothermal resources is compounded by established state and federal policies that hobble geothermal development. Unsuitable provisions of state and federal leases, obstructive applications of state water laws, and ambiguous or discriminatory tax statutes cripple the geothermal industry. Federal energy research and development financing has also failed to encourage large-scale geothermal development. Instead, it has treated geothermal resources as an exotic phenomenon to be studied rather than employed.[4]

Such policies accentuate the uncertainty and risk already inherent to geothermal exploration and development. For geothermal resources to contribute substantially to U.S. energy supply, state and federal policies must instead encourage investments in geothermal exploration, field development and powerplant construction.

STATE POLICIES FOR GEOTHERMAL RESOURCES

The most prominent geothermal resources occur in the fifteen gulf and western states. In each state, authority and guidelines have been established for administration of geothermal leasing and for regulation of development. Important matters addressed by these policies include:

a) resource definition: describes the resource subject to geothermal policies
b) leasing provisions: specify the manner of leasing and lease obligations
c) development regulations: control well-drilling and production for purposes of safety and resource conservation
e) water appropriation: fix the applicability of state water laws to geothermal development
f) environmental standards: regulate the permissible effects of geothermal development on the environment

Several other policy areas that have major consequences for geothermal development have not in general received the attention of state policymakers. These policy issues include:

g) taxation: property, severance, income and other special taxes bear importantly on geothermal development
h) securities regulations: state securities commissions and the federal Securities and Exchange Commission can expand or contract the supply of capital available to geothermal developers
i) utility regulations: utility investments and power transmission are two important policy areas within utility commission jurisdiction

In all these areas, established state and federal policies are frequently unresponsive to the needs of geothermal development. Current policies either predate geothermal operations in the United States, or where new geothermal statutes and regulations have been enacted, they derive largely from existing policies for water and petroleum development. Past experience with these resources has been misleading, however, when applied to geothermal resources. Established policies as a result often present obstacles to geothermal development, rather than encouragement.

The following conditions are needed for the geothermal industry to pursue large-scale development:

- consumer (utility) confidence in the resource
- equitable tax treatment
- prompt exploration of extensive land areas
- long and secure tenure for productive properties
- prompt facility siting and development
- competitive access to various consumers

With these conditions, the geothermal industry should be competitive with other energy sectors and able to win its share of investment capital. Specific policies to achieve these conditions are suggested below, and additional background is presented in the body of this report. The chapter notes and bibliography will give direction for further readings. In particular, the *Geothermal World Directory* (Glendora, California: Katherine F. Meadows) should be referred to for a catalog of persons directly involved with geothermal development. Other sources of current information include:

a) *Geothermal Energy Magazine* (West Corvina, California: Geothermal Energy Association);
b) Geo-Heat Utilization Center *Quarterly Bulletin* (Klamath Falls, Oregon: Oregon Institute of Technology);
c) ERDA program announcements; for example: *Geothermal Project Summaries* (ERDA 76-53);
d) "Grid" computerized bibliography of geothermal literature and "Geotherm" computerized data file on geothermal fields, wells and other geothermal topics; both projects being developed at the Lawrence Laboratories in California;
e) "Geocost" computer model of development economics for geothermal reservoirs and powerplants; this program may be accessed through the Argonne National Laboratories (developed for ERDA by Battelle Pacific Northwest Laboratories, Richland, Washington).

Country	Electric Power (MW)		Non-Electric (MW)
	Operating	*Planned*	
Hungary	....	....	380
Iceland	3	55	285
Italy	406	15	15
Japan	43	75	25
Mexico	79	75	....
New Zealand	170	210	120
United States	413	196	15
U.S.S.R.	6	20	5100
El Salvador	....	30	....
Guadaloupe	....	30	....
Turkey	....	10	....
TOTAL	1120	716	5940

Fig. 2. Approximate electric and non-electric geothermal energy use in 1975 (from Howard, "Principle Conclusions," figures 2-4, table 1)

SUGGESTED POLICIES

1) INFORM CITIZENS OF THE IMMEDIATE AND LONG-TERM VALUE OF GEOTHERMAL RESOURCES.

Geothermal reserves could supply a major portion of the western states' energy needs with relatively minor environmental impacts. Actual development will be controlled by the citizenry — by key policymakers, interest groups and the broader public. Their knowledge of geothermal resources will be reflected in financial, professional and political choices critical for the geothermal industry.

The public increasingly is a direct participant in development decisions. The National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA), for example, establish public review as a necessary stage of major development projects. Current nuclear referenda underline the importance of public opinion for energy use and supply. During the review of power development projects, therefore, states should direct public attention to geothermal resources as a serious alternative. State administrative and legislative officers should be educated concerning geothermal resources, and descriptive reports should be vigorously disseminated to the broader public. Public hearings, news releases and public school programs may all be employed. Energy alternatives are central to energy planning, and knowledge of all supplies, including geothermal energy, is necessary — for the planning specialist and for the general public.

To realize the benefits of geothermal resources, public policies encouraging development are needed. These will depend on the initiative of policymakers and on supportive public opinion. Both can be stimulated by knowledge of the values available from geothermal resources.

2) CREATE AN INTERSTATE GEOTHERMAL DEVELOPMENT COMPACT.

The purpose of the compact would be continued improvement of governmental policies and policy administration for geothermal resources. The compact would represent state interests in all matters affecting geothermal development.

Communications between the states, and between states and geothermal developers, would be emphasized by the compact. Mutual understanding could be promoted through workshops, internships, publications and other exchanges. And through the compact, states could contribute to — and benefit from — models for geothermal legislation and regulatory codes.

Many aspects of geothermal development are dominated by federal policies. Federal land policy; regulations of the FPC, IRS, SEC and EPA; research and demonstration by ERDA; and legislation or agency actions affecting water appropriation will be critical to the geothermal industry. The compact would work with federal agencies and the U.S. Congress to encourage policies for large-scale development of geothermal resources and for other special geothermal concerns of the states.

In addition, the compact could be empowered to demonstrate the feasibility of geothermal powerplants. All power production and use is interrelated in the gulf and western states, and any demonstration projects would be authorized in light of this mutuality.

3) CLARIFY THE STATUTORY DEFINITION OF GEOTHERMAL RESOURCES AND THEIR RELATION TO OTHER NATURAL RESOURCES.

Each known type of geothermal system, including magma, hot dry rock, geopressured and hydrothermal convection systems, should be identified as a geothermal resource with its properties and components accurately described. The statutory definition would provide a reference to clarify all other public policies affecting geothermal resources and development; these include leasing, field development regulations, property tax levies and assessment methods, income tax deductions and utility commission regulations. The definition would also guide legal and private determinations concerning geothermal resources.

Geothermal resources should be clearly distinguished from other natural resources. Established water resources, in particular, should be separated from geothermal resources. The distinction can be made in a number of ways. Fluids and vapors found in geothermal formations may be defined as a component of the system. In this case, a minimum geothermal formation temperature (e.g., 80°C) may be specified to separate geothermal systems from water bodies. Ground fluids from lower temperature formations would not be considered a geothermal resource.

Where fluids or vapors in geothermal formations are not defined as a component of the geothermal resource, they may still be distinguished from established water resources through appropriation procedures. The fluids produced from geothermal formations may be declared as developed waters or by some other method declared as distinct from established water resources; the developer's absolute right to such fluids could be rebutted only if interference with established water rights were demonstrated.

Interference with existing water rights is a concern in geothermal development however the fluids may be legally treated. Any adequate definition of geothermal resources will recognize that geothermal fluids grade into standard groundwater under some circumstances, but that a rule is needed to separate them where no interference exists. Water rights must be protected. At the same time, conjectured interference should not obstruct geothermal development. To satisfy both necessities, the states should provide by statute that regardless of their categorization, fluid or vapor production from geothermal formations is not restricted by established water rights unless substantial interference can be demonstrated.

4) PROVIDE BY STATUTE THAT WHERE WATER APPROPRIATION IS NECESSARY FOR GEOTHERMAL DEVELOPMENT, OR FOR PRODUCTION OF WATER FOR ITS HEAT CONTENT, ONLY THE CONSUMPTIVE USE REASONABLY NECESSARY FOR THE INTENDED APPLICATION NEED SECURE AN APPROPRIATION RIGHT.

In production, large volumes of fluid are drawn from geothermal formations. Over 98,000 acre-feet (31.6 billion gallons) per year of hot water may be required to supply a 200 MW powerplant. But in most cases less than 20% of the fluid is consumed, mostly in evaporation cooling. If groundwater at 85-100°F is used with heat-pumps for heating and cooling, virtually all of the water is available for subsequent use.

In some states (for example, Utah and Nevada), water rights are necessary for the entire water volume diverted for use. In others, water appropriation requirements may be limited by administrative practice to consumptive use. In all cases, however, geothermal power development, or other applications of ground fluid for its heat value, need statutory assurance that required permits for water appropriation will be restricted to consumptive use. If production of fluid depends on water rights for the entire volume, geothermal development may suffer severely from a legal water shortage.

5) ESTABLISH UNIFORM STATE GUIDELINES FOR ASSESSMENT OF GEOTHERMAL PROPERTIES. IN PARTICULAR, STIPULATE IN STATE ASSESSMENT STANDARDS FOR TAXATION OF REAL PROPERTY THAT NO INCOME VALUE WILL BE ATTRIBUTED TO PROSPECTIVE GEOTHERMAL PRODUCTION BEFORE GEOTHERMAL RESOURCES ARE PRODUCED FROM THE PROPERTY IN COMMERCIAL QUANTITIES.

The geothermal market suffers now from the uncertainty of electric utilities about resource supply. Only deep drilling can prove the commercial potential of a geothermal reservoir, and few areas have been drilled. Reportedly, about one exploratory geothermal well has been drilled monthly, compared to 600 for oil and gas.

A large base of geothermal reservoirs defined through drilling would therefore strengthen the market for geothermal resources. But if anticipated income value for the property is assessed before income accrues, such a base would also be a large tax liability providing no income for several years. Long delays occur between the discovery of geothermal resources and their commercial use. The resource must be employed on-site, so that delays for siting permits and the construction of electric generating facilities are added to the time required for field development. Development is in fact uncertain even after the resource is proven, since there is no assurance that the resource will have a market. In contrast, petroleum development can generate revenue from the first producing well.

Ad valorem assessment of *anticipated* income from undeveloped geothermal properties for this reason creates a deterrent to widespread development. Property tax on a 200 MW field could be over $2 million annually.

In summary, difficulties with ad valorem assessment of geothermal resources before commercial production include the following: 1) it forces local assessors to make judgements for which there is insufficient knowledge and experience; 2) it taxes property long before the assessed income value can possibly be realized; 3) it imposes pressure for development irrespective of actual economic, environmental and social values of the development; 4) it militates against investment to prove the capacity of geothermal reservoirs; and 5) it is ineffective in preventing land speculation.

To remove this tax obstacle, the states should assess geothermal income value only upon commercial production. Within the ad valorem structure, one approach is suggested by Arizona's provision concerning property speculation. The state code provides that where market data are used, the amount of property value due to speculation on future income is to be excluded from the appraisal. Because estimates of future income from undeveloped geothermal properties are quite speculative, commercial production should be required as proof that anticipated income from geothermal properties is nonspeculative.

6) EXTEND INCOME TAX DEDUCTIONS FOR INTANGIBLE DRILLING COSTS AND PERCENTAGE DEPLETION TO GEOTHERMAL DEVELOPMENT TO MAINTAIN PARITY WITH OTHER ENERGY INDUSTRIES. THE FEDERAL INCOME TAX CODE SHOULD BE AMENDED, AND STATE INCOME TAXES INDEPENDENT OF FEDERAL PROVISIONS SHOULD EXTEND THESE DEDUCTIONS TO GEOTHERMAL OPERATIONS.

Federal income tax is the largest levy faced by geothermal developers and investors alike. Tax benefits for investment in petroleum drilling funds, or percentage depletion deductions for income from coal or uranium properties, strongly affect the flow of capital to these investments. They reduce investment risk and enhance its return. The depletion deduction also provides developers with equity to expand operations.

To finance significant development of geothermal resources, the industry must go to the capital markets. An investor faced with a decision between two drilling prospects, one for geothermal resources and one for oil and gas, will not need to hesitate if tax benefits are only associated with petroleum investments. Geothermal development is the unknown, and without tax benefits to ameliorate investment risk at least comparable to the other energy sectors, the geothermal industry will not command its share of investment capital.

7) REVIEW STATE GEOTHERMAL LEASING POLICY TO ELIMINATE PROVISIONS UNSUITED TO GEOTHERMAL DEVELOPMENT; ALSO PROMOTE SIMILAR REVIEW AND REVISION OF LEASING POLICY BY THE FEDERAL GOVERNMENT.

Lease terms and renewal arrangements, minimum acreage limitations and lease adjustment clauses should provide the scope and security necessary for widespread employment of geothermal resources.

A hot-water geothermal reservoir may typically be expected to underlie 10-15 acres of land for every megawatt of electric generation capacity. Dozens of prospective fields will generally be explored before discovering a reservoir with commercial capacity. Large amounts of acreage must therefore be leased for exploration, and several tracts (7000-20,000 acres each) will need to be examined simultaneously to offset the high exploration risk.

Conformance with limits on maximum leasholdings per state, like the federal limit of 20,480 acres/state, prevents adequate holdings. Evasion through dummy operators, etc., is thereby encouraged. And to the extent that proven or productive acreage is not excluded from acreage limitations, successful geothermal developers are blocked from further exploration. Such overly restrictive acreage limitations should be revised upward to correspond with the practical needs of geothermal development.

Because geothermal resources are employed on-site, lease terms must provide long-range security necessary to amortize the facilities. Thirty to forty years are needed for geothermal powerplants. And since geothermal fields will be developed in stages—this is one of their attractions—lease arrangements also need to allow for amortization of facilities installed ten or more years after the lease begins. Ambiguity in renewal and adjustment clauses will simply block large capital investments in powerplant or industrial facilities.

The federal government is a dominant landholder in most geothermal states. It is important, therefore, that the states also work to establish federal lease provisions suited to geothermal development.

8) STATE PUBLIC UTILITY COMMISSIONS SHOULD ADOPT POLICIES WHICH STRENGTHEN THE GEOTHERMAL MARKET.

Policies should be examined which require access to established transmission lines for geothermal power producers, exempt commercial power producers from utility status, provide financial incentives for utility investments in geothermal powerplants, grant facility siting priority to geothermal applications, or otherwise encourage production of geothermal power.

Utilities plan and make construction commitments for installed capacity ten years in advance. A geothermal reservoir developed in the service area of a utility fully committed must therefore wait a decade for income if access to transmission lines is obstructed. If that particular utility is unusually conservative, or has special commitments to other power sources, marketing the resource may be impossible for the geothermal developer. At $150,000 to $200,000 per mile, construction of new transmission lines is not feasible for the incremental, small module (55-110 MW) development characteristic of geothermal power. Access to established transmission lines may therefore be critical to widespread development of geothermal resources.

Utilities can be directly enncouraged to invest in geothermal projects through various financial incentives, and also indirectly by private or governmental demonstration projects for geothermal powerplants. Private demonstration can be stimulated by exempting commercial geothermal power suppliers from "utility" status, provided they generate electricity for sale to utilities. Regulatory control of electric power would in this way be maintained. Wheeling rights would still be necessary to expand the market for geothermal power.

9) PROMOTE NON-ELECTRIC APPLICATIONS OF GEOTHERMAL RESOURCES.

State and local governments should appraise opportunities for direct use of the earth's heat in agriculture, industrial processes, or the heating and cooling of buildings, and these uses should be encouraged through public information, zoning laws, building codes and financial incentives.

Heat applications at temperatures less than 250°C (typical of geothermal formations) account for 40% of total U.S. energy consumption. This heat is now supplied by natural gas, fuel oil, coal and electricity. The work potential of these high-grade fuels is largely wasted when consumed for such low-temperature purposes. This inefficient use may be unavoidable when no other adequate heat source is available. In the gulf and western states, however, heat from the earth may be used directly for agricultural and industrial processes and for heating and cooling of buildings. The drain on petroleum supplies can thereby be lessened and new electric demand reduced. Direct use of the earth's heat is also its most efficient use. In general, no more than 20% of the heat's energy at these temperatures can be converted to electricity.

Notes

1) California Resources Agency, "Water and Power from Geothermal Resources," pp.9-10.

2) In 1973 the Regional Electric Reliability Councils projected a capacity of 1,676,571 MW for the U.S. in 1993 (Federal Power Commission, "News Release No. 20692," September 24, 1974). Geothermal development of 100,000 MW would equal about 6% of this total. The electric potentials of geopressured and hydrothermal convection reservoirs, assessed by the U.S Geological Survey, combined equal 200,000 MW to 400,000 MW. If these resources, plus hot dry rock areas, are aggressively developed, 5-10% of U.S. electric capacity by 2000 appears to be a reasonable goal for geothermal power. (A similar estimate may be found in Futures Group, *A Technology Assessment of Geothermal Energy Resource Development*, pp. 1, 13.) For the longer term, igneous systems alone may potentially supply several million megawatts of power. (See later discussion of geothermal reserves.)

3) Richard G. Bowen, "Environmental Impact of Geothermal Development," p.200.
Impacts which may occur in geothermal development include pollution from vented gases, well blow-outs and land subsidence. Technologies are available to control the occurrence of these possible impacts, and their importance varies widely among geothermal areas. (See later discussion of environmental protection.)

4) The federal government has budgeted $56 million for geothermal research and development for the 1977 fiscal year. No demonstration plants are planned prior to the 1980s. The federal geothermal loan guaranty program is budgeted an additional $50 million. (The cost of a 200 MW geothermal project is over $150 million.) The amounts for geothermal R&D are small relative to funds alloted, for example, to fusion ($392 million) or fission ($1,255 million). Geothermal loan guaranties for $50 million should also be compared to the $2,000 million in guaranties proposed for synthetic fuels. (*A National Plan for Energy Research, Development and Demonstration* (ERDA 76-1), pp.37,40,41)

2

Features of the Resource

ORIGIN AND POTENTIAL

For centuries hot mineral springs have been visited for their therapeutic and recreational values. During the last decades, however, improved technology for exploration, well drilling and electric conversion has made geothermal energy available for a much broader range of purposes. The earth's internal heat is a major energy resource, and this potential has begun to be realized.

Globally, geothermal powerplants generate approximately 1500 megawatts (MW) of electric power. Equally important are direct heat applications. The Soviet Union, Hungary, Iceland and New Zealand are foremost in direct use, employing between themselves some 6000 MW in agriculture, industrial processing and for heating and cooling of buildings. (Fig. 2) In the United States, The Geysers dry-steam field north of San Francisco provides 500 MW of electric power—enough to supply a city of one-half million—and geothermal energy is used directly for heating at Klamath Falls, Oregon; Boise, Idaho; and other scattered locations.[1]

In terms of its potential, the present use of geothermal energy is small. The earth is an immense reservoir of heat, and for over 3,500 million years energy has steadily flowed from the interior to the planet's surface. This energy has been generated annually at a rate equivalent to at least ten times last year's world energy consumption, which if supplied by burning coal, would have required a layer 40 miles thick.[2]

Most geothermal energy in fact does not derive from chemical processes. Like the other major energy options—solar, fusion and fission power—geothermal energy results from nuclear processes.* Radioactive thorium, potassium and uranium distributed more or less evenly in the earth's crust yield heat as they decay. These elements are very long-lived, with half-lives of several billions of years, and their heat will continue without fail for millenia.[3]

While the earth's store of thermal energy is tremendous, the heat's practical value depends on our ability to effectively employ it. This becomes increasingly difficult as the heat grows diffuse; it is impossible when the heat lies behind rock shields tens of miles thick. Geothermal energy, like petroleum, is transferred to the surface through wells, and these cannot be drilled commercially beyond about 10 kilometers (33,000 feet) because of high cost and technical limitations.[4]

For most of the earth's surface, temperatures accessible by drilling are too low to be economically employed. Geothermal development therefore involves a search for heat reservoirs relatively near the earth's surface. Many valuable sites have been found in the United States and in other areas of the world. (Fig. 1) The pattern of such discoveries reflects the basic geologic structure of the planet.

Plate Tectonics

The earth's crust is composed of giant plates of solid rock. These are in motion relative to one another. Where they spread apart, molten rock underlying the crust flows upward and builds onto the receding plates. Where the plates impact, the crustal rock is forced downward and melts into the interior. At these junctures heat travels from the molten interior to the inhabited surface.[5] (Fig. 3)

High volcanism along crustal faults reveals the upwelling of magma which brings internal heat near to the surface. Fissures at the plate junctures also allow cool surface waters to penetrate downwards to great depths: when heated, the water returns upward by convection, sometimes appearing at the surface as hot springs and geysers. The intrusion of magma near to the surface and deep circulation of surface waters make the earth's high interior temperatures potentially available for use. Along the plate junctures, therefore, lie the most promising high-temperature geothermal areas.

In the United States, a plate juncture runs from the Gulf of California northward, including the San Andreas fault, along the Cascade Mountains of Oregon and Washington to Alaska, where it parallels the southern coast through the Aleutian Islands.

Another high-temperature structure runs along the Rocky Mountains. Thermal springs and geysers at Yellowstone National Park are the most prominent geothermal evidence of the mid-continent structure. These

*Some heat also is generated by compression and friction at crustal faults and plate junctures. Exothermic chemical reactions may contribute heat in some locations.

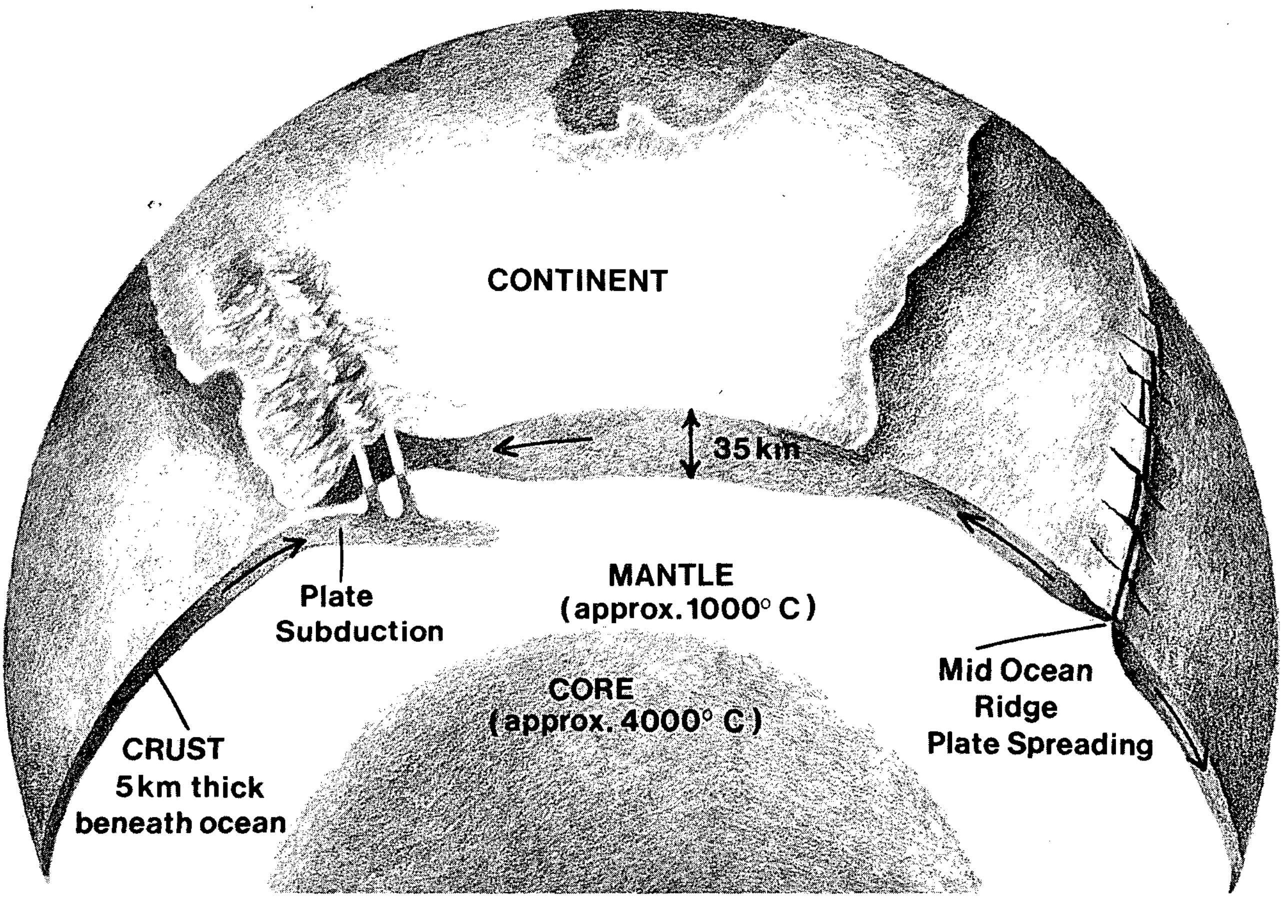

Fig. 3. Earth cross-section. At growth and subduction boundaries of crustal plates magma rises to or near the earth's surface.

two geologic features are part of a major geothermal area covering the western continental states and portions of Alaska. The Hawaiian Islands are a discrete volcanic occurrence not closely associated with a major crustal structure. But certainly near-surface magma chambers are a rich geothermal base for the island state.[6]

GEOTHERMAL ACREAGE

Almost three million acres in eighty-two locations have been classified by the U.S. Geological Survey as known geothermal areas (KGRA). These sites are currently the most promising in the country for geothermal development. An additional 100 million acres are considered prospectively valuable for geothermal development. Acreages within each state are given in Figure 4 and indicated on the accompanying maps.[7] (Figs. 5-7)

The federal government owns little land in Texas, Louisiana and Hawaii, and no area designations have been made for these states. Nevertheless, all three contain valuable geothermal areas. In Texas and Louisiana, geopressured reservoirs underlie an extensive region, as shown in Figure 8, totalling approximately 375,000 km^2 (93.6 million acres).[8]

State	KGRA (1967)	Prospectively Valuable (1967)	KGRA (1975)
Alaska	....	....	88,160
Arizona	....	1,694,000	3,240
California	838,000	16,324,000	1,399,709
Colorado	....	2,002,000	20,825
Hawaii*	....	....	....
Idaho	16,000	14,102,000	120,042
Louisiana*	....	....	....
Montana	18,000	6,226,000	58,655
Nevada	38,000	13,200,000	487,940
New Mexico	140,000	7,414,000	198,687
Oregon	....	14,432,000	367,652
Texas*	....	....	....
Utah	....	4,554,000	118,209
Washington	....	5,236,000	35,613
Wyoming	....	743,000	..........**

*Hawaii, Louisiana and Texas contain very little federally-owned land. The U.S. Geological Survey has not classified lands, although extensive geothermal resources occur in these states.

**Yellowstone National Park includes geothermal resources. These are not developable under current regulations and the acreage is not included here.

Fig. 4. Classified geothermal acreage (from Abt Associates Inc., *Energy Resources*, p.E-4; U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975)

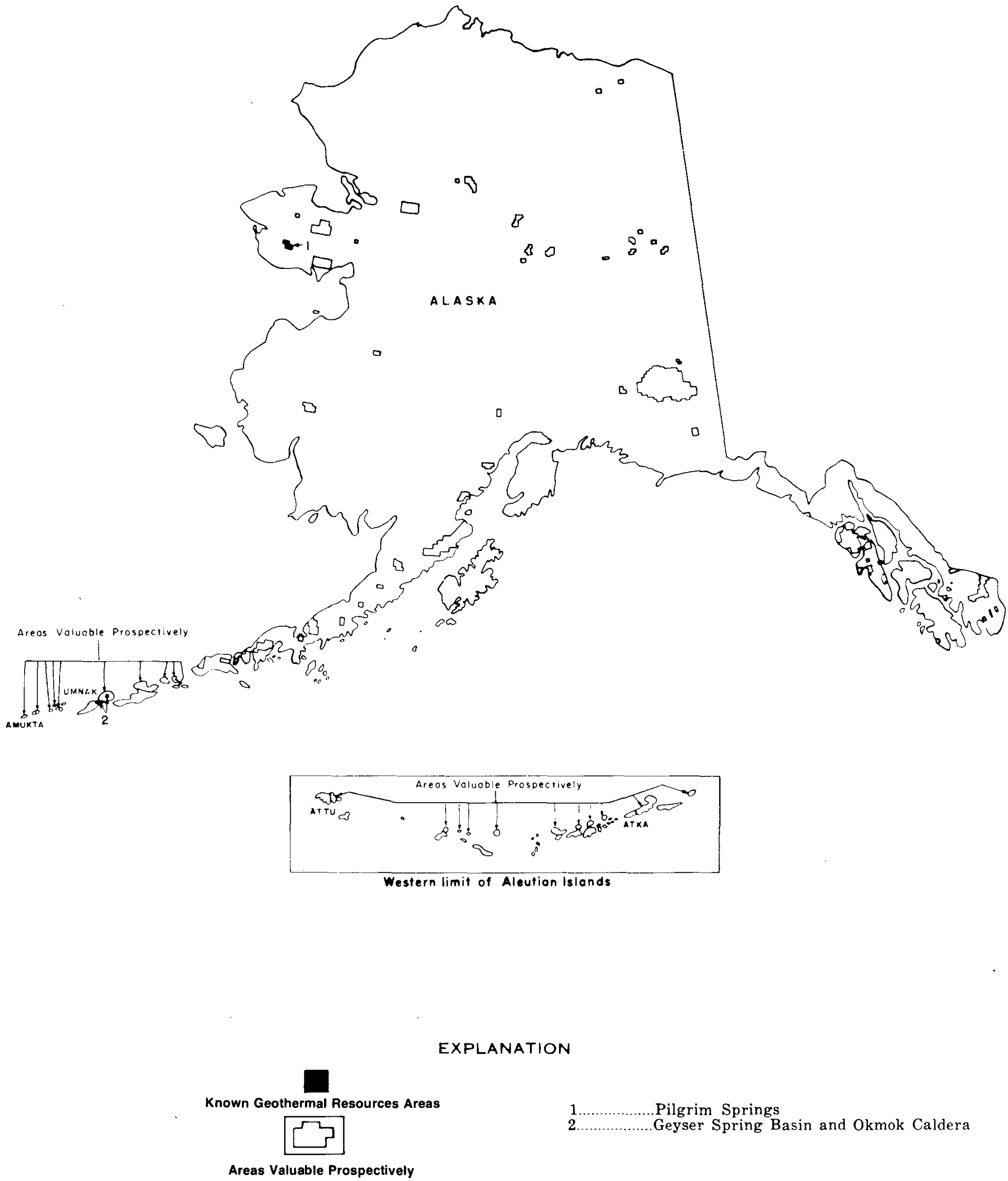

Fig. 5. Map of classified geothermal acreage in Alaska (from Godwin et al., "Classification of Public Lands," figure 1)

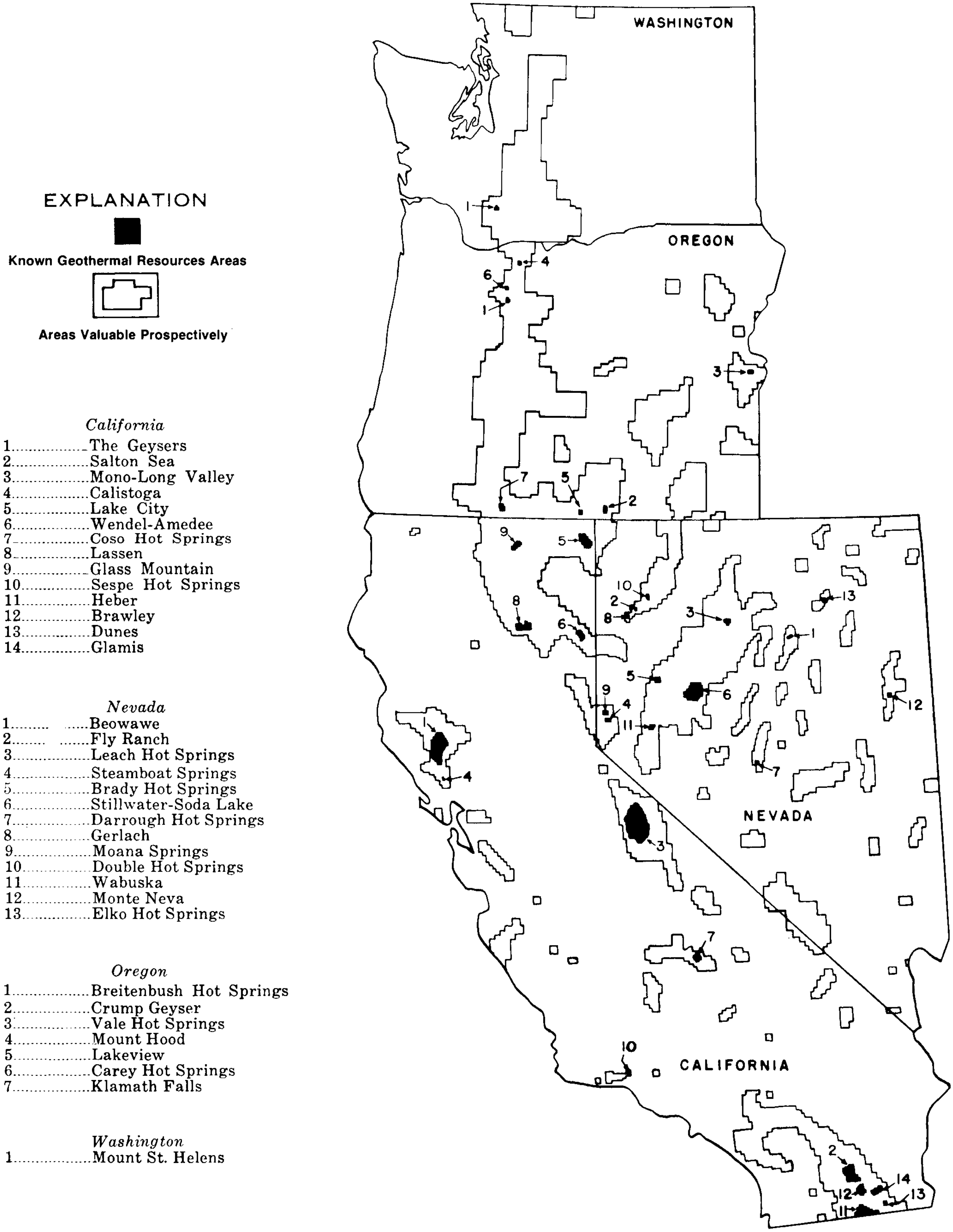

Fig. 6. Map of classified geothermal acreage in California, Nevada, Oregon and Washington (from Godwin et al., "Classification of Public Lands," figure 2)

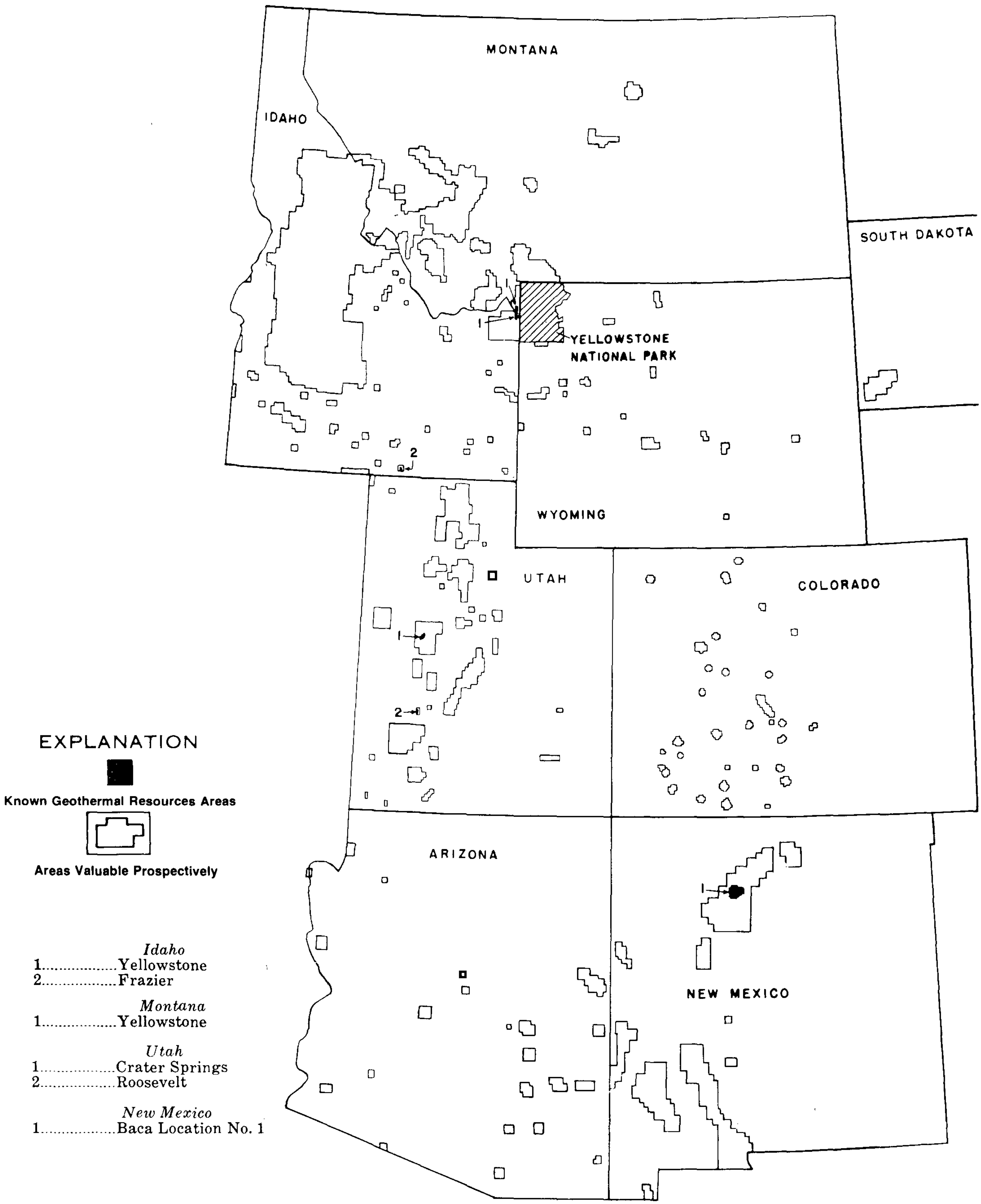

Fig. 7. Map of classified geothermal acreage in Rocky Mountain states (from Godwin et al., "Classification of Public Lands," figure 2)

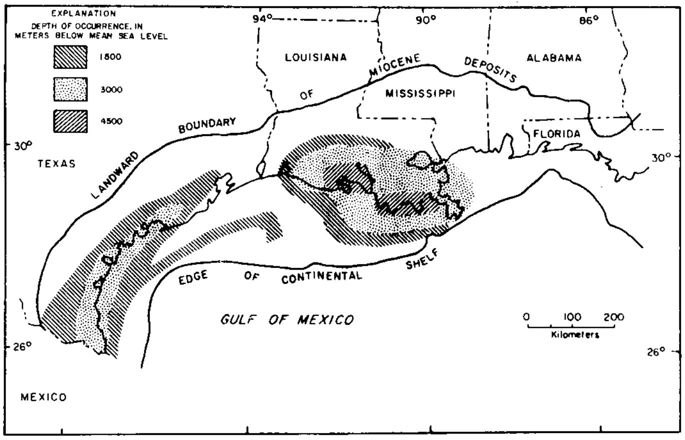

Fig. 8. Map of potential gulf coast geopressured resources (from Dorfman and Deller, *Second Geopressured Geothermal Energy Conference*, Vol. I, figure 1)

HIGH-TEMPERATURE RESERVOIRS

Volcanic intrusion to or near the surface and deep circulation of surface waters along crustal faults form high-temperature geothermal regimes. Four types may usefully be distinguished. These are 1) magma, 2) hot dry rock, 3) water-dominated, and 4) vapor-dominated systems.

Magma and Hot Dry Rock

Where magma chambers lie sufficiently near the surface to be penetrated by drilling, they are themselves a potential resource. Their very high temperatures (700°C to 1600°C) make them both attractive and problematic. The hazards of drilling at such extreme temperatures and associated pressures are great. One study of the present ability to directly tap magma is underway at Sandia Laboratories, with field tests anticipated for Hawaii.[9]

Magma chambers rarely lie near the surface. More generally, magma intrudes just close enough to the surface to heat the overlying rock to high temperatures. To be utilized, the rock's heat must then be brought to the surface. Water naturally present may form a hydrothermal convection system. If water is not present—hot dry rock—it (or some other heat transfer medium) must be supplied.

The rate of heat transfer to the surface is the critical factor, and this depends on the rock temperature and on the surface area in contact with the water. The water must circulate in the rock. If the rock is impermeable—the expected situation—it must be fractured to create a large surface area for heat exchange to the water. Explosives or pressurized water may be employed. Under pressure, water induces a vertical "pancake" fracture in the rock, and cool water will extend the fracture by thermal stress.[10]

If the rock should happen to be naturally permeable, a reverse problem may result. Unless the permeable area is confined, injected fluid may simply be lost without achieving a circulating system.

As may be expected, hot dry rock areas are extensive compared with hydrothermal or magma systems. Hot rock at temperatures above 290°C (550°F) has been estimated to underlie 95,000 square miles (61 million acres) of the western states at a depth of 5 km (16,400 feet).[11] Magma systems are a special case in which molten rock is accessible to drilling. Hydrothermal systems are hot rock formations where circulating fluid occurs naturally, transporting heat toward the surface.

Well costs will be critical to the economic feasibility of hot dry rock development. These relate directly to the depth at which suitable temperatures are reached. In addition, rock fracturing techniques to allow heat transfer still must be demonstrated. If rock fracturing is successful, areas with 290°C rock at 5 km depth should support electric generation at costs fully competitive with fossil or nuclear power.[12]

Hydrothermal Convection Systems

Vapor-dominated and water-dominated reservoirs are two types of hydrothermal convection systems which differ basically only in the amount of fluid present. The geologic structures are the same. A deep water-bearing strata of permeable rock (aquifer) permits fluid circulation to basement high-temperature rock.* Above the aquifer in high-temperature formations, an impermeable caprock prevents the rapid diffusion of the reservoir heat. Faulting is generally present and restricts the lateral loss of geothermal fluid. A fluid's natural tendency to circulate in columns also reduces dispersion of heat.[13] (Fig. 9)

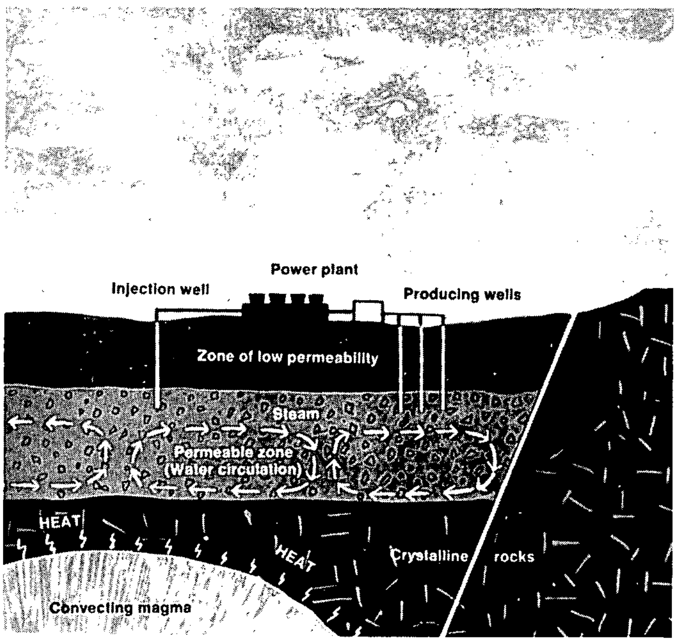

Fig. 9. Hydrothermal convection reservoir schematic (courtesy of Pacific Gas and Electric Company)

* Two types of aquifers may be identified. One type, which includes sandstone, is rather like a fine-pored rigid sponge. Other aquifers result from fracturing of otherwise impermeable rock. Any permeable rock formation can serve as a good geothermal reservoir: The Geysers (impermeable graywacke with fissure permeability); Larderello, Italy (carbonate rock with karstic permeability, i.e., limestone region heavily structured and faulted); Wairakei, New Zealand (fissured ignimbrite); Otake, Japan (permeable deltaic sands).[15]

Fluid in most convection systems has originated at the surface from precipitation of rain or snow. The fluid has percolated downward through porous topsoil and then along cracks, faults and through permeable rock strata. This form of fluid is termed meteoric.**[14]

Water-Dominated. As the volume of liquid increases in a reservoir, boiling at depth is prevented. This is due to the rapid increase with depth of hydrostatic pressure and the corresponding boiling temperature. Figure 10 gives pressure and boiling point for water to depths of 7000 feet. Boiling temperatures are much higher at the indicated depths than found even in most high-temperature geothermal areas. Under these circumstances, a water-dominated reservoir is formed, with temperature and pressure equilibriums controlled by fluid circulation. Hydrostatic pressure will fall sufficiently to permit boiling if deep fluids which have retained their high temperature circulate to near the surface.[17]

Depth (ft)	Hydrostatic Pressure (psi)	Boiling Temperature (°C)
500	225	200
1000	450	236
2000	900	278
3000	1350	306
4000	1800	327
5000	2250	345
6000	2700	360
7000	3150	373

Fig. 10. Subsurface pressure and boiling temperature of water (data from Chemical Rubber Company, *Handbook of Chemistry and Physics*, 47th ed., table for vapor pressure of water, p.D-107)

Vapor-Dominated. Dry-steam or vapor-dominated reservoirs may occur when a shallow table of water lies near a (usually deep) high heat source, with the inflow of water restricted to no more than reservoir losses. Hydrostatic pressure is thereby limited, and the fluid will boil at depth. Under an impermeable caprock, a steam system rather like a pressure cooker forms. Some steam venting is usually present, and surface waters will be heated by the steam and steam condensate.[18]

MEDIUM-TEMPERATURE RESERVOIRS

High-temperature reservoirs located along crustal faults are not the only exploitable geothermal formations. In those same locations, lower temperature reservoirs may exist where the source-heat is more remote, more diffused in reaching the surface, or less completely trapped.[19] If reservoirs are similar except for temperature, the higher temperature formation is the more valuable. Higher temperatures inherently can do more work. Nevertheless lower temperature fluids may warrant exploitation.

Another type of medium-temperature reservoir may exist far from crustal faults. Rock strata in the crust which conduct heat poorly will accumulate regional heat flow and can form a medium-temperature regime. The temperature of a particular strata will depend both on its heat conductivity and on the heat flow at that location.

The sedimentary basin of southwestern Hungary is an important example of this type of formation. At depths of 1800 to 2000 meters, geothermal wells produce 85°C to 130°C water.[20] This is twice the temperature normally expected at 2000 meters. The Hungarians make extensive use of this resource in space heating and for agriculture. Several hospitals and factories and 2100 apartments are heated geothermally. In Budapest, 5600 apartments are supplied with geothermal hot water. Farm uses are equivalent to over 400 MW of power. The costs of geothermal space heating in Hungary, even before the rise in oil prices, were less than half the alternative coal, oil and natural gas prices.[21]

Geopressured Reservoirs

The sedimentary basin along the Texas and Louisiana gulf coasts is another medium-temperature regime. At depths from 1500 to 15,000 meters (5000 to 50,000 feet), connate fluids in porous rock strata several hundreds to thousands of feet thick are sealed between impermeable layers of clay and shale.[22] (Fig. 11)

As a result of faulting, these aquifers are partitioned into large vaults, in some cases hundreds of square miles in extent.[23]

Shale and water are poor conductors of heat, and water has a high heat storage capacity (about five times that of most rock). These layers of trapped fluid consequently have stored large quantities of heat energy.

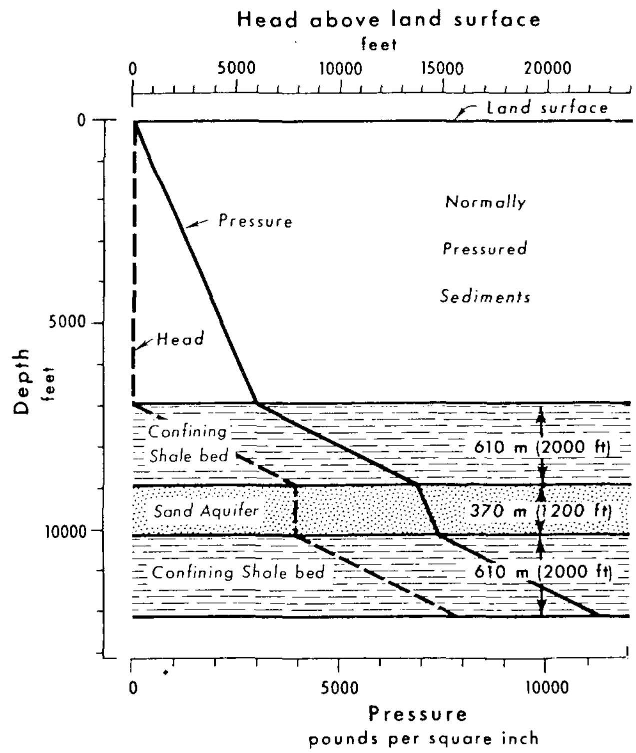

Fig. 11. Section of idealized geopressured reservoir showing assumed head and pressure variation with depth (from Papadopulos, "Hydrogeologic Factors," figure 2)

** Not all geothermal fluid is meteoric. Some originates in the underlying magma. Water is also trapped during the formation of rock strata. These types of fluid are termed magmatic and connate. The geopressured geothermal reservoirs of the Louisiana and Texas gulf coast are the most important occurrence in the United States of connate geothermal fluid.

Temperatures of the fluids range from 90°C to over 200°C (200° to 400°F). (Fig. 12) The unusual temperatures are thought to result not only from the low conductivity of the confined formations, but also from unusually high heat flow. The solid crust along the gulf coast and underlying the continental shelf is believed to be comparatively thin, with high-temperature magma close to the surface.[24]

Geothermal reservoirs along the gulf coast in addition have two valuable aspects not typical of geothermal formations in the other western states. The reservoirs have unusually high pressures, and the fluid is generally saturated with natural gas. Fluid in the reservoirs is at extraordinary pressure because it is bearing part of the weight of overlying rock—that is, it is geopressured. Typical reservoir pressures may range, varying with depth, from 5000 psi to 13,000 psi.[25] (Fig. 13) This mechanical pressure can be converted to electricity with efficiency as high as 90%, and in some instances, it may account for half of the available electric energy for the geopressured reservoir.[26]

The other resource constituent, methane, is expected to exist at saturation in most gulf coast geopressured reservoirs.[27] Its solubility in the geothermal fluid varies with temperature and pressure, and therefore the amount of methane produced in a barrel of fluid will depend on specific reservoir conditions.[28] (Fig. 13)

At 10,000 psi and 300°F, the saturated methane content for the fluid would be about 40 standard cubic feet (scf) per barrel of fluid. With a well-flow rate of 85,000 barrels/day, natural gas production for the well would be 3400 thousand cubic feet (mcf) per day. These conditions may be expected of a typical reservoir at 15,000 feet.[29] At $2.00/mcf, the gross income per well for natural gas alone would be $6800/day—almost $2.5 million per year. Clearly natural gas is an important energy constituent of geopressured reservoirs.

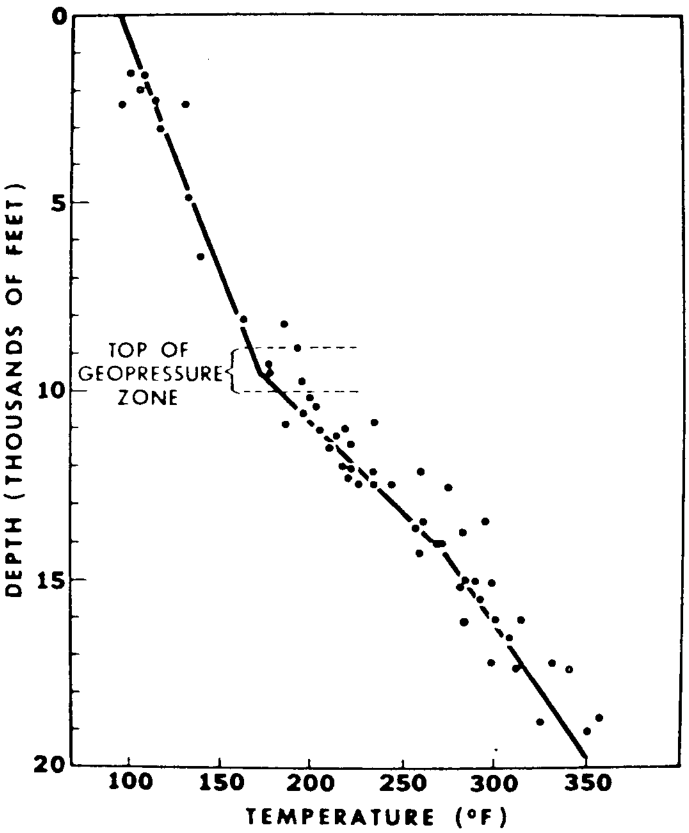

Fig. 12. Maximum temperatures recorded in boreholes in Cameron County, Texas (from Jones, "Geothermal and Hydrocarbon Regimes," figure 34)

Pressures and Temperatures for Typical Geopressured Reservoirs

Depth (ft)	*Pressure (psi)*	*Temperature (°F)*
5,000-10,000	5,100	200
10,000-15,000	9,100	250
15,000-20,000	12,800	300

The solubility of methane in the geothermal fluid varies with temperature and pressure. Therefore the amount of methane produced in a barrel of fluid depends on specific reservoir conditions.

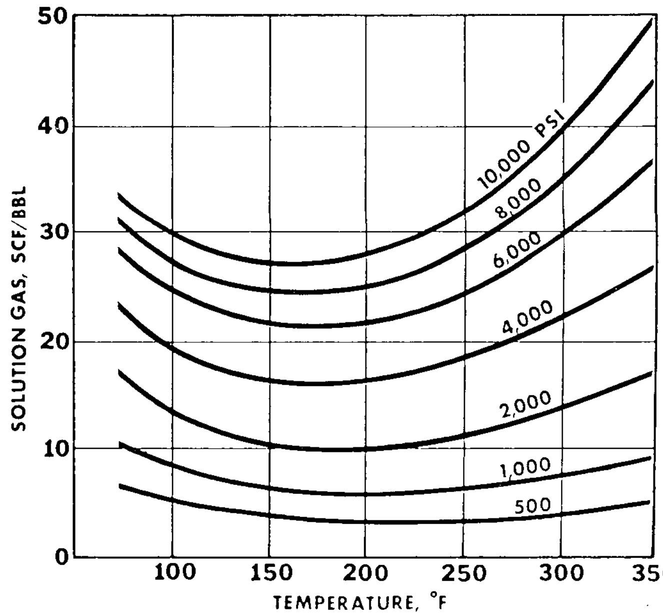

Fig. 13. Temperature, pressure and methane content expected for gulf coast geopressured reservoirs (from Jones, "Geothermal and Hydrocarbon Regimes," figure 58; House, Johnson and Towse, "Potential Power Generation," p.285)

GEOTHERMAL BYPRODUCTS

Methane in geopressured reservoirs is a byproduct of the geothermal system. It is produced by the action of heat and pressure on organic substances deposited in the sedimentary basin.[30] In different formations other types of byproducts occur. Minerals and gases dissolve in water, especially as its temperature increases. Metals and insoluble minerals intermixed with the soluble elements also become entrained in geothermal fluids.

Brines produced from some areas of the Imperial Valley of California are an outstanding example of geothermal fluids high in mineral content. The dollar values of these minerals if they were separated are quite impressive. Gross amounts for a typical well are: potash ($5,000/day); silver ($280/day); borax ($480/day); lead ($125/day); zinc ($650/day); lithium ($30,000/day).[31] In the past, potash (KCl) and carbon dioxide have been commercially produced near Niland.[32]

Water itself may in some cases be an important geothermal byproduct. The fluid heat may be used through distillation or other processes to demineralize the water.[33] Where water is scarce and valuable, as in the Imperial Valley, production of both water and minerals may be economical. A U.S. Bureau of Reclamation project is testing this possibility at East Mesa in the Imperial Valley.[34]

GEOTHERMAL RESERVES

Heat is a ubiquitous form of energy. Beneath every point on the earth's surface lies an ocean of magma at 1000°C. Heat is common, in fact, to all substances at temperatures above absolute zero (-273.16°C). But available technology and the costs of resource development limit geothermal "reserves" to a fraction of the earth's total heat.

In 1975, the U.S. Geological Survey completed an initial assessment of geothermal resources in the United States.[35] The study calculated the amount of heat energy stored in geothermal formations hotter than 15°C to a depth of 10km. (Hydrothermal systems were assessed only to a depth of 3km.) The portion of this resource base available for development with existing technology was also estimated according to three separate cost assumptions. Geothermal resources recoverable at costs competitive with current energy resources were designated "reserves"; those recoverable at costs between one and two times current energy prices as "paramarginal resources." "Submarginal resources" were estimated to be recoverable at more than two times present energy costs.

System	Volume* (km³)	Electrical Potential (MW for 30 years)
The Geysers, CA (Dry Steam)	140	1570
Surprise Valley, CA	250	1100
Long Valley, CA	450	6020
Salton Sea, CA (Imperial Valley)	108	2760
East Mesa, CA (Imperial Valley)	56	480
Heber, CA (Imperial Valley)	100	960
Brawley, CA (Imperial Valley)	27	330
Beowawe Hot Springs, Nev.	42	620
Brady Hot Springs, Nev.	30	390
Steamboat Springs, Nev.	16	210
Valles Caldera, N.M.	130	1970
Cove Fort - Sulphurdale, Utah	22.5	270
Yellowstone Nat'l Park, WY	940 (with 6.5 km³ dry steam system)	> 10,000

*These volume estimates are themselves limited by the hypothetical exclusion of convection or reservoir depth below 3 km.

Fig. 14. Volume and electrical energy potential for thirteen well-explored geothermal systems (from Nathenson and Muffler, "Geothermal Resources," Table 16)

Hydrothermal Convection Systems	Area (km²)
Identified High-Temperature	1,500
Identified Medium-Temperature	3,000
Known Geothermal Resources Areas	11,600
Propectively Valuable Areas	400,000

Fig. 15. Area comparison for identified and potential hydrothermal convection systems (from Renner, White and Williams, "Hydrothermal Convection Systems," tables 3-5; U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975)

Total stored heat as calculated in the U.S.G.S. study is shown in Figure 16. Estimates of recoverable electric power were made only for geopressured and high-temperature hydrothermal convection reservoirs. These appear in Figures 17 & 18. No estimates were made for the other geothermal formations as electric conversion technology was not considered adequately developed. Their heat content, however, is very great. If heat in igneous systems were extracted and converted with the same efficiency as in high-temperature hydrothermal reservoirs, the power from 100,000 × 10^{18} calories would be approximately 3.2 million megawatts for 100 years (100,000/1200) × 38,000 = 3.2 × 10^6.

The U.S.G.S. estimates show that geothermal resources have a large electric generation capacity. High-temperature hydrothermal convection systems are evaluated at approximately 30,000 MW for 100 years, or 100,000 MW for 30 years, at prices between one and two times current power costs. While only a portion of total geothermal potential, this represents a significant fraction of the country's present electrical capacity of some 500,000 MW.

Although large, these tentative heat and power estimates are in fact conservative. A paucity of facts concerning geothermal formations led to minimizing assumptions. The assessment of igneous systems, for example, included 48 out of 151 identified volcanic intrusions within 10 km of the surface, and assumed that no preheating or recharge of these chambers had ever occurred. Injection or convection of fresh magma dramatically increases the available heat of such formations, but minimum assumptions were adopted in the absence of other evidence. According to the U.S.G.S. researchers, igneous heat content may be at least ten times greater than the assigned value.[36]

The assessment of known hydrothermal convection systems similarly minimized calculated heat values. Temperatures for most reservoirs were estimated according to the chemical composition of geothermal fluids at the surface. These chemical "thermometers" provide rough approximations and in many instances may underestimate reservoir temperatures.[37]

The U.S.G.S. calculation accounts for heat stored in hydrothermal reservoirs only to a depth of 3 km; this is the depth of current geothermal drilling, but just half the depth commonly reached today by oil wells. It assumes no heat recharge by fluid convection from below 3 km,

	Identified systems: Number	Identified systems: Heat Content (10^{18} cal)*	Identified + estimate for undiscovered: Heat Content (10^{18} cal)*
1. *Hydrothermal convection systems* (to 3 km depth, ~10,000 ft, near the maximum depth drilled in geothermal areas)			
Vapor-dominated (steam) systems	3	26	~50
High-temperature hot-water systems (over 150°C)	63	370	~1,600
Intermediate-temperature hot-water systems (90° to 150°C)	224	345	~1,400
Total	290	~741	~3,050
2. *Hot igneous systems* (0 to 10 km)			
Molten parts of 48 best known, including Alaska and Hawaii		~13,000	
Crystallized parts and hot margins of same 48		~12,000	
Total		~25,000	~100,000
3. *Regional conductive environments* (0 to 10 km; all 50 states subdivided into 19 heat-flow provinces of 3 basic types, Eastern, Basin-and-Range, and Sierra Nevada)			
Total, all states		~8,000,000	~8,000,000
Overall total		8,025,741	8,103,050

*10^{18} calories equivalent to heat of combustion of ~690 million barrels of petroleum or ~154 million short tons of coal.

Fig. 16. Heat content of U.S. geothermal resources estimated without regard to recoverability (from White and Williams, *Assessment of Geothermal Resources of the United States – 1975*, p.148)

	Heat in ground (10^{18} cal)[1]	Heat at well-head (10^{18} cal)[2]	Conversion efficiency	Beneficial heat (10^{18} cal)[3]	Electrical energy (MW·cent)[4]	MW for 30 years[5]
High-temperature systems (>150°C; for generation of electricity)						
Identified resources	257	64	0.08 to 0.2			
Reserves					3,500	11,700
Paramarginal resources					3,500	11,700
Submarginal resources					>1,000[6]	> 3,300[6]
Undiscovered resources	1,200	300	0.08 to 0.2		38,000[7]	126,700[7]
Intermediate-temperature systems (90° to 150°C; mainly non-electrical uses)						
Identified resources	345	86	0.24	20.7		
Undiscovered resources	1,035	260	0.24	62.1		
TOTAL	2,837	710		82.8	46,000	153,400

[1]10^{18}cal (a billion-billion calories) is equivalent to heat of combustion of 690 million barrels of oil or 154 million short tons of coal.

[2]Assumed recovery factor 0.25 for all convective resources.

[3]Thermal energy applied directly to its intended thermal (non-electrical) use; 10^{18}cal of beneficial heat, if supplied by electrical energy, would require at least 1,330 MW·cent (or 4,400 MW for 30 years); however, a user of this geothermal energy must be located or must relocate close to the potential supply; insufficient data available to predict demand or to subdivide into reserves, paramarginal, and submarginal resources.

[4]Unit of electrical energy; 1 MW·cent is equivalent to 1000 kw produced continuously for 100 years.

[5]Assumes that each MW·cent of electricity can be produced at rate of 3.33 MW for 30 years.

[6]Small because of exclusion of systems with temperatures below 150°C.

[7]Perhaps as much as 60 percent will be reserves and paramarginal resources; costs of discovery and development are more speculative than for identified resources.

Fig. 17. Recoverable energy from U.S. hydrothermal convection reservoirs (from White and Williams, *Assessment of Geothermal Resources of the United States – 1975*, p.150)

	Heat in pore fluids, (10^{18}cal)[1]	Percent recovery (heat only)	Heat equivalent at well-head (10^{18}cal)[2]	Conversion efficiency	Electrical energy, MW·cent[3]	MW for 30 years
Gulf Coast geopressured fluids in sediments of Tertiary age; assessed on-shore parts only, to depth ranging up to 7 km.	10,920					
Thermal energy		0.021	229.4	0.08	24,380	81,260
Methane (thermal equivalent)			124.2		[5]	[5]
Mechanical energy (thermal equivalent)			9.4	0.80	9,970	33,230
TOTAL			363.0		34,350[6]	114,490[6]
Other unassessed parts of Gulf Coast geopressured environment, on-shore and off-shore to 10 km[7]	22,000		>500		>50,000	>166,700
Other geopressured environments to 10 km[7,8]	11,000		>250		>25,000	> 83,300

[1]Thermal energy only; 10^{18}cal is equivalent to heat of combustion of 690 million barrels of oil.

[2]All plans assume 0.15 m^3/sec flow rate per well and saturation of water with methane, but reliable data lacking.

[3]Unit of electrical energy; 1 MW·cent is equivalent to 1000 kw produced continuously for 100 yrs.

[4]Estimates made for 20 yr. production period; converted to 30 yrs. to be consistent with other estimates of this circular.

[5]Methane assumed recovered but not used locally for electricity.

[6]Perhaps in part reserves but mostly paramarginal, depending on environmental and other costs.

[7]Thermal equivalent of methane included in heat at well-head but excluded from electrical energy; recoverable part highly speculative because of unknown porosities and permeabilities, but probably largely submarginal.

[8]No detailed assessment but considered likely to exist in California and other states.

Fig. 18. Recoverable energy from onshore geopressured reservoirs of Texas and Louisiana. Plan maximizes total recovery over 20-year period; no pressure decline below 2000 psi; 17,160 wells; subsidence of 5-7 meters (from White and Williams, *Assessment of Geothermal Resources of the United States – 1975*, pp.151-152).

and unless other information is available, the top of the reservoir is set at 1.5 km. These assumptions yield a reservoir thickness of 1.5 km.

As pointed out in the U.S.G.S. report, areas assigned to hydrothermal reservoirs also may be too small by as much as three orders of magnitude (×1000). In many instances no information was available to establish areas, and they were set at 1.5 km^2.

As a consequence of these assumptions, many of the evaluated hydrothermal systems were assigned a volume of 2.25 km^3. This figure may be compared to volumes determined for relatively well-explored reservoirs. (Fig. 14)

The volumes of explored fields suggest that identified but unexplored systems may often be larger than 2.25 km^3 by at least a factor of twenty. This is supported by evidence that extinct volcanic/hydrothermal systems typically have ranged from several tens to hundreds of cubic kilometers in volume.[38]

For purposes of calculation, a depth limit of 3km and minimum area assignments of 1.5 km^2 are useful since areas, recharge rates and depths are not known for most of the reservoirs. It is important to note, however, that these assumptions result in minimum values for hydrothermal reserves.

The identification of new hydrothermal systems will of course multiply geothermal reserves. The U.S.G.S. report suggests that new discoveries will total about five times known reserves. One indication of the extent of undiscovered reserves is the amount of land classified known or prospectively valuable for geothermal development. These areas and the areas assigned in the U.S.G.S. study to identified systems appear in Figure 15.

Conclusions

The U.S.G.S. assessment argues that a large portion of U.S. electrical needs may be supplied by geothermal resources. High-temperature hydrothermal reservoirs with total capacity exceeding 100,000 MW may be developed immediately. Geopressured reservoirs store an additional 110,000 MW to 300,000 MW. This potential makes geothermal power a major energy source now and in the immediate future. Over the intermediate and long term, hot rock areas, magma systems, intermediate-temperature hydrothermal systems, and deep geothermal resources offer a vast store of energy for development.

The ability of geothermal resources to supply energy in direct heat applications is more difficult to assess. The fundamental limitation is not accessible heat, but geographically matching geothermal energy to various agricultural, industrial, commercial and domestic heat uses.[39] An important program for the states is identifica-

State	Total Acreage	Federally Owned	Percent Federal	State Owned	Percent State	Private & Other	Percent Private
Alaska	365,482	348,467	95.3	13,506*	3.7	3,508	1
Arizona	72,688	32,433	44.6	9,222	12.7	31,033	42.7
California	100,207	44,394	44.3	2,110*	2.1	53,702	53.6
Colorado	66,486	24,152	36.3	3,233	4.9	39,101	58.8
Hawaii	4,106	397	9.7	1,497*	36.4	2,212	53.9
Idaho	52,933	33,849	63.9	2,755	5.2	16,330	30.9
Louisiana	28,868	1,042	3.6	201*	0.7	27,624	95.7
Montana	93,271	27,654	29.6	5,275	5.7	60,342	64.7
Nevada	70,264	50,725	86.4	86	0.1	9,453	13.5
New Mexico	77,766	26,388	33.9	11,032	14.2	40,346	51.9
Oregon	61,599	32,180	52.2	1,652*	2.7	27,767	45.1
Texas	168,218	3,004	1.8	3,448*	2.0	161,766	96.2
Utah	52,697	35,060	66.5	4,923	9.3	12,714	24.2
Washington	42,694	12,570	29.4	3,237*	7.6	26,887	63.0
Wyoming	62,343	30,060	48.2	3,902	6.3	28,382	45.5

*Excludes submerged and off-shore lands

Fig. 19. Land ownership (× 1000 acres) in the fifteen geothermal states (from Pearl, McDonald and Hughes, *State Land Resources and Policies*, table 33)

tion of such opportunities. Whenever geothermal energy is applied directly, the drain on natural gas, oil and coal is lessened and new electric capacity requirements reduced. The potential savings are considerable. Heat applications at less than 250°C, which are temperatures typical of geothermal formations, account for 60% of total U.S. energy consumption, excluding fuels used in transportation and as chemical feedstocks.[40]

OWNERSHIP OF GEOTHERMAL RESOURCES

The complex character of geothermal resources has made assignment of ownership difficult. Water, dissolved minerals and gases, and heat are standard constituents. In some instances, pressure is also a feature of the resource.

Water typically has been attached to the surface estate or held as a public resource. Minerals and gases are associated with the subsurface estate and may be severed from the surface. Heat—which distinguishes the geothermal resource—and pressure are not directly appropriable and lack established ownership histories.[41]

This heterogeneity assures that numerous actors will appear during the development of geothermal resources. Land owners and those who control the water or minerals for geothermal properties may all claim control of the geothermal resource. These incipient conflicts are not yet settled. The relative influence of different property interests may be suggested, however, by the patterns of surface, mineral and water ownership in the gulf and western states.

Land Ownership

The extent of private, federal and state lands varies widely among states. The results of a 1968 survey by the Public Land Law Review Commission[42] are shown in Figure 19.

Federal ownership accounts for 30-50% of the land in most states, although exceptions lie at both extremes: Texas (1.8%), Louisiana (3.6%), Hawaii (9.7%), Nevada (86.4%) and Alaska (95.3%).

State ownership, in contrast, remains consistently low in all states. Only Hawaii holds land appreciably in excess of 10% of the surface. Nevada and Louisiana own very little land, with only 0.1% and 0.7% of the surface.

The rule for land ownership, therefore, is that 90% of the surface is divided between the federal government and private parties, with the remainder controlled by the states.

State	Total	Mineral Reserved
Alaska	*	*
Arizona	10.5 million	1 million
California	2.8 million	529,000 188,000 (1/16 interest)
Colorado	4 million	1 million
Hawaii	2.7 million	1.1 million
Idaho	3 million	245,000
Louisiana	5 million**	....
Montana	6 million	625,000
Nevada	....	....
New Mexico	13 million	2 million
Oregon	2.4 million**	100,000
Texas	15.5 million**	7.5 million
Utah	3.6 million	919,000
Washington	3.5 million	500,000
Wyoming	4.2 million	600,000

*Figures not available
**Includes offshore acreage

Fig. 20. Mineral acreage held by states

State	All Minerals	Oil & Gas	Oil & Gas plus other	Misc. Minerals	Stockraising Homestead Acreage
Alaska	6,501	1,095	773	....	....
Arizona	2,547,517	27,497	....	101,880	2,985,746
California	2,352,070	156,783	23	1,864	3,423,222
Colorado	4,271,042	215,423	38,494	....	8,405,015
Hawaii	....	....	....	....	....
Idaho	1,291,163	4,940	216,060	....	3,563,294
Louisiana	1,223	17,105	3,844	....	....
Montana	3,993,640	987,472	17,788	150	7,720,173
Nevada	242,717	1,119	80	40	494,637
New Mexico	6,378,118	112,995	70,673	2,092,091	15,621,192
Oregon	1,639,742	14,369	480	....	3,375,688
Texas	....	....	....	....	....
Utah	856,093	98,922	8,157	1,680	2,800,709
Washington	262,444	2,518	384	400	513,746
Wyoming	9,541,179	376,906	17,341	257	18,172,194

The above acreage was patented, with the indicated reservations, through 1948. After 1948, statistics were no longer kept by state. Approximately 15% more land was patented with mineral reserves through 1974.

Fig. 21. Acreage patented with minerals reserved to the United States (from U.S. Bureau of Land Management, *Public Land Statistics – 1974*, tables 17,29)

Mineral Ownership

In the conveyance of land to other parties, federal and state practice has often been to reserve specified substances, such as oil, or in more general language, simply the "minerals." Consequently, surface ownership patterns do not completely reflect established resource rights. Surface and subsurface estates have been created subject to independent ownership and control; the proper attachment of geothermal resources to one of these estates, or to a separate category, has become a matter of litigation.[43]

The amount of land at issue within each state is considerable. As seen in Figure 20, several states control at least one million acres of mineral reserve.[44] Figure 21 lists acreage patented through 1948 with minerals reserved to the federal government. After 1948 statistics were not kept by state; in aggregate, approximately 15% more land was patented from 1948 to 1974 with minerals reserved.

Groundwater Ownership

Groundwater in most states is controlled by the state as a public resource. Exceptions are Arizona, California, Hawaii, Louisiana and Texas. In these five states, groundwater is attached to the surface, unless critical groundwater areas are designated. In such areas, water rights are adjudicated.

State requirements for water appropriation are critical for geothermal development. Extension of certain water regulations to production of geothermal fluids may seriously obstruct their development. Alternative policies therefore should be sought which protect water rights without suppressing geothermal development. This problem is considered more fully in Chapter 5.

Geothermal Leasing

Federal Lands. As of October 1975, the federal government had competitively leased land in seven states totalling 216,282 acres. Cumulative income to the federal treasury from cash bids was over $14 million, or an average of $66.78/acre. (See Appendix 3)

By October 1975, 5027 non-competitive lease applications had also been filed. Of these, 381 (7.6%) were awarded leases covering 686,376 acres. (Fig. 22)

State Lands. Six states have granted geothermal leases covering a total of about 364,000 acres.[45] (Fig. 22) Among these states, California also issues three-year exploration permits which may be converted to leases in the event of a discovery. (Leasing policies are discussed in a later chapter.) Fifteen active exploration permits currently cover 52,304 acres in California.[46]

State	Federal Leases		State Leases
	Competitive	*Non-Competitive*	
Arizona	....	6,508	....
California	36,592	1,280	4,523
Colorado	5,036	13,421	117,806
Idaho	2,600	67,052	54,874
Nevada	54,977	371,770	....
New Mexico	18,477	106,130	19,881
Oregon	49,037	5,774	8,240
Utah	49,563	114,441	158,594
Totals	216,282	686,376	363,918

Fig. 22. Acreage of state and federal geothermal leases (from U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975)

Notes

1) J. H. Howard, "Principle Conclusions of the Committee on the Challenges of Modern Society Non-Electric Applications Project," Tables 1-5;
James B. Koenig, "Worldwide Status of Geothermal Resources Development," pp. 15-18.

2) Edward Bullard, "Basic Theories," p.22;
Chauncey Starr, "Energy and Power," *Scientific American*, Vol. 225, No.3, September 1971.

3) Bullard, "Basic Theories," p.22.

4) Wilton Gravley, "Drilling Mechanics of On-Shore Wells," pp.5-35.

5) Bullard, "Basic Theories," pp.23-30.

6) Ibid.; Donald E. White, "Characteristics of Geothermal Resources," pp.70-71.
The Hawaiian Islands trace the path of the Pacific plate over a crustal "hot spot." See Kevin C. Burke and J. Tuzo Wilson, "Hot Spots on the Earth's Surface," *Scientific American*, Vol. 235, No.2, August 1976, p.46.

7) U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975;
L. H. Godwin et al., "Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources," U.S. Geological Survey Circular 647.

8) Paul H. Jones, "Geothermal and Hydrocarbon Regimes, Northern Gulf of Mexico Basin," p.40;
Stavros S. Papadopulos et al., "Assessment of Onshore Geopressured-Geothermal Resources in the Northern Gulf of Mexico Basin," p.125.

9) D. L. Peck, "Recoverability of Geothermal Energy Directly from Molten Igneous Systems," pp.122-124.

10) Morton C. Smith, "Progress of the LASL Dry Hot Rock Geothermal Energy Project," pp.207-213;
Abt Associates, Inc., *Energy Fuel Mineral Resources of the Public Lands*, Vol.I, p.E6.

11) Donald W. Brown, "The Potential for Hot-Dry-Rock Geothermal Energy in the Western States," pp.1-9.

12) Stanley L. Milora and Jefferson W. Tester, *Geothermal Energy as a Source of Electric Power* (Draft), Figures 26A-C. Cooling 40 cubic miles of rock from 290°C to 90°C would yield 6.8×10^{16}BTU (equivalent to the energy content of all the oil on the North Slope of Alaska). (Futures Group, *Technology Assessment*, p.42) The energy from 95,000 square miles of rock one mile thick would be:

$(6.8 \times 10^{16}\text{BTU}/40\ \text{mi}^3) \times (95{,}000\ \text{mi}^3) = 1.6 \times 10^{20}\text{BTU}.$

Converted with 10% efficiency to electricity, this heat energy would yield 4.8×10^{12}MW-hrs, which equals the output of 6 million megawatts of power generated over 100 years at 80% plant capacity. In other words, economically promising hot rock areas have a potential electrical generating capacity on the order of twelve times the present U.S. electric capacity of 500,000 MW maintained for 100 years.

13) White, "Characteristics of Geothermal Resources," pp.69-94.

14) Ibid., pp.75-77. At Larderello, Italy, infiltration of local "young" meteoric water appears to contribute at most 1/3 of reservoir fluid. The remainder is from deep circulation of regional water and deposits prior to exploitation. Cesare Petracco and Paolo Squarci, "Hydrological Balance of Larderello Geothermal Region."

15) Giancarlo Facca, "The Structure and Behaviour of Geothermal Fields," p.63.

16) Jones, "Geothermal and Hydrocarbon Regimes," p.28.

17) White, "Characteristics of Geothermal Resources," pp.75-82.

18) Ibid., pp.82-87.

19) Facca, "Geothermal Fields," p.64.

20) Koenig, "Worldwide Status," p.44.

21) Tibor Boldizsar, "Geothermal Energy Use in Hungary," p.113;
Howard, "Principle Conclusions," Table 3.

22) Jones, "Geothermal and Hydrocarbon Regimes," p.40;
Palmer A. House, P. M. Johnson and D. F. Towse, "Potential Power Generation and Gas Production from Gulf Coast Geopressured Reservoirs," p.283.

23) William J. Bernard, "Reservoir Mechanics of Geopressured Aquifers," p.160.

24) Jones, "Geothermal and Hydrocarbon Regimes," pp.48-60; p.21 and Fig.1.

25) House, Johnson and Towse, "Potential Power Generation," p.285;
Stavros S. Papadopulos, "The Energy Potential of Geopressured Reservoirs: Hydrogeologic Factors," p.178.

26) House, Johnson and Towse, "Potential Power Generation," pp.287,288,349.

27) Papadopulos, "Hydrogeologic Factors," pp.187-188.

28) Jones, "Geothermal and Hydrocarbon Regimes," p.79.

29) House, Johnson and Towse, "Potential Power Generation," p.289.

30) Jones, "Geothermal and Hydrocarbon Regimes," p.76.

31) Abt Associates, Inc., *Energy Resources*, pp.E8-9.

32) Koenig, "Worldwide Status," p.33.

33) Baldur Lindal, "Industrial and Other Applications of Geothermal Energy," pp.138-139.

34) U.S. Bureau of Reclamation, *Geothermal Resource Investigations: East Mesa Test Site*, November 1974.

35) Donald E. White and David L. Williams, eds., *Assessment of Geothermal Resources of the United States – 1975*, U.S. Geological Circular 726.

36) R. L. Smith and H. R. Shaw, "Igneous-Related Geothermal Systems," pp.73,76.
Neither does the estimate include oceanic volcanic systems. Exploitable chambers may lie in the Gulf of California. David L. Williams, "Evaluation of Submarine Geothermal Resources."

37) J. L. Renner, D. E. White and D. L. Williams, "Hydrothermal Convection Systems," pp.37-42. These pages indicate numerous reservoirs which may have temperatures as much as 100°C higher than those actually assigned to them.

38) Ibid., p.56.

39) Gordon M. Reistad, "The Potential for Non-Electric Applications of Geothermal Energy and Their Place in the National Economy."

40) Ibid., Figures 1 and 6.

41) Donald B. Elmer and Kathryn Rogers, "Legal Issues in the Development of Geopressured-Geothermal Resources of Texas and Louisiana Gulf Coast," p.96.

42) Milton A. Pearl, Joseph M. McDonald and Eugene E. Hughes, *State Land Resources and Policies*, Part II.

43) United States v. Union Oil Company of California et al., Civil No.72-1866 GBH, N.D. Cal., October 30, 1973. In this case the court ruled against the plaintiff: that geothermal steam and associated resources were not included within a reservation pursuant to the federal Stockraising Homestead Act of "all the coal and other minerals in the lands so entered and patented, together with the right to prospect for, mine and remove the same."
Harry Pariani et al. v. State of California, No.75314, Superior Court of California, Sonoma County. Ruling May 28, 1976. In this case the court ruled in favor of the plaintiff: that the underlying geothermal steam system belongs to the owner of the mineral rights.
See the briefs for these cases: also, Elmer and Rogers, "Legal Issues," pp.69-103.

44) Acreages given for state mineral lands are based on conversations with state land offices; they are only rough approximations.

45) In Arizona, a moratorium on leasing of state lands has been imposed by the state supreme court. At issue is the state's ability to lease resource rights non-competitively. (Information on leasing for several states courtesy of Donald Finn, Geothermal Energy Institute, San Francisco: Oral Communication.)

46) California State Lands Division (Long Beach), "Geothermal Leases and Prospecting Permits," 1975.

3

Exploration and Development

EXPLORATION

Exploration must locate a field capable of supporting electrical generation at a feasible cost. The factors which determine the suitability of a given reservoir are its temperature, depth, fluid productivity, fluid quality and productive lifetime.

The first step in exploration is a review of existing literature to identify prospective areas. Features are sought in the geology, hydrology and surface characteristics indicative of geothermal potential. Attractive possibilities are pursued by examination of the site using various geophysical and geochemical survey techniques. Geothermal development rights should be secured for the most promising areas.[1]

At this stage, prospects are surveyed further and temperature holes located. Temperature holes range in depth from several feet to a few hundred feet and are used to measure increases in temperature (thermal gradient). The normal thermal gradient between 15 meters and 150 meters is approximately 3°C per 100 meters. In general, geothermal exploration seeks thermal gradients at these depths in excess of 7°C per 100 meters.[2]

Surface exploration methods are inferential and can be misleading in numerous ways. Nevertheless, they give fairly strong indications of a geothermal reservoir's depth, minimum temperature and fluid characteristics. On the other hand, they do not reveal the reservoir's ability to produce fluid.[3]

Reservoir productivity is controlled by its fluid supply and permeability (the rate at which fluid can move through the acquifer). As a rule, these factors are determined only by drilling into the formation. Permeability, for example, may vary even within a reservoir. Local variation is characteristic of fracture permeability as found at The Geysers or Wairakei, New Zealand.[4]

Remaining major unknowns after surface exploration require that geothermal exploration undertake deep drilling. Well location is dictated by results from the preceding exploration, as well as local topography and other environmental factors. If a strong producing zone is encountered, the well-bore is cased and prepared for testing. Additional step-out wells are used to prove the reservoir's production capacity.[5] (Fig. 24)

Exploration Costs

Field exploration, exclusive of deep drilling, typically costs \$12 - \$16/acre and commonly encompasses 2000 to 10,000 acres. For very large tracts (50,000 acres), the cost per acre for exploration may decrease by as much as 50%.[6] Representative total and hourly costs to explore a 7500 acre tract are given in Figure 23. They suggest that approximately five to six months are required for surface exploration of the tract at a cost of \$12/acre.[7]

The cost of deep exploration wells can vary considerably, depending on characteristics of the formation and final well depth. Typically, however, well costs between \$365,000 and \$550,000 may be assumed.[8] These costs are examined more fully in the review of field development.

Exploration Method	Cost/Month	Total	Time
Geology	\$3,000-\$4,000	\$10,000	3 months
Geochemistry & mineralogy	\$10,000-\$15,000	\$5,000	15 days
Groundnoise & microseismic	\$20,000-\$45,000	\$15,000	15 days
Resistivity	\$15,000-\$25,000	\$20,000	30 days
Temperature Holes	\$40,000-\$50,000	\$40,000	30 days

Fig. 23. Exploration costs for a 7500-acre tract (from Greider, "Status of Economics," figures 7-9)

Exploration Risk

It is important to remember that exploration does not necessarily provide a discovery. Almost certainly several tracts will be surveyed before finding one suitable for deep exploratory drilling. Neither will all tracts warrant equally thorough examination. Exploration expenditures will differ between them.

To estimate exploration expenditures required to discover a producible reservoir, one needs a schedule of probable successes. Figure 25 is based on an estimate of statistical success developed by Robert Greider of Chevron Oil Company. On the average, according to his figures, 64 tracts of 7500 acres will be explored before discovery of a field capable of supporting 200 MW in electrical generation.[9]

For the 200 MW field itself, investment in exploration up to step-out wells is \$597,500. The statistical cost,

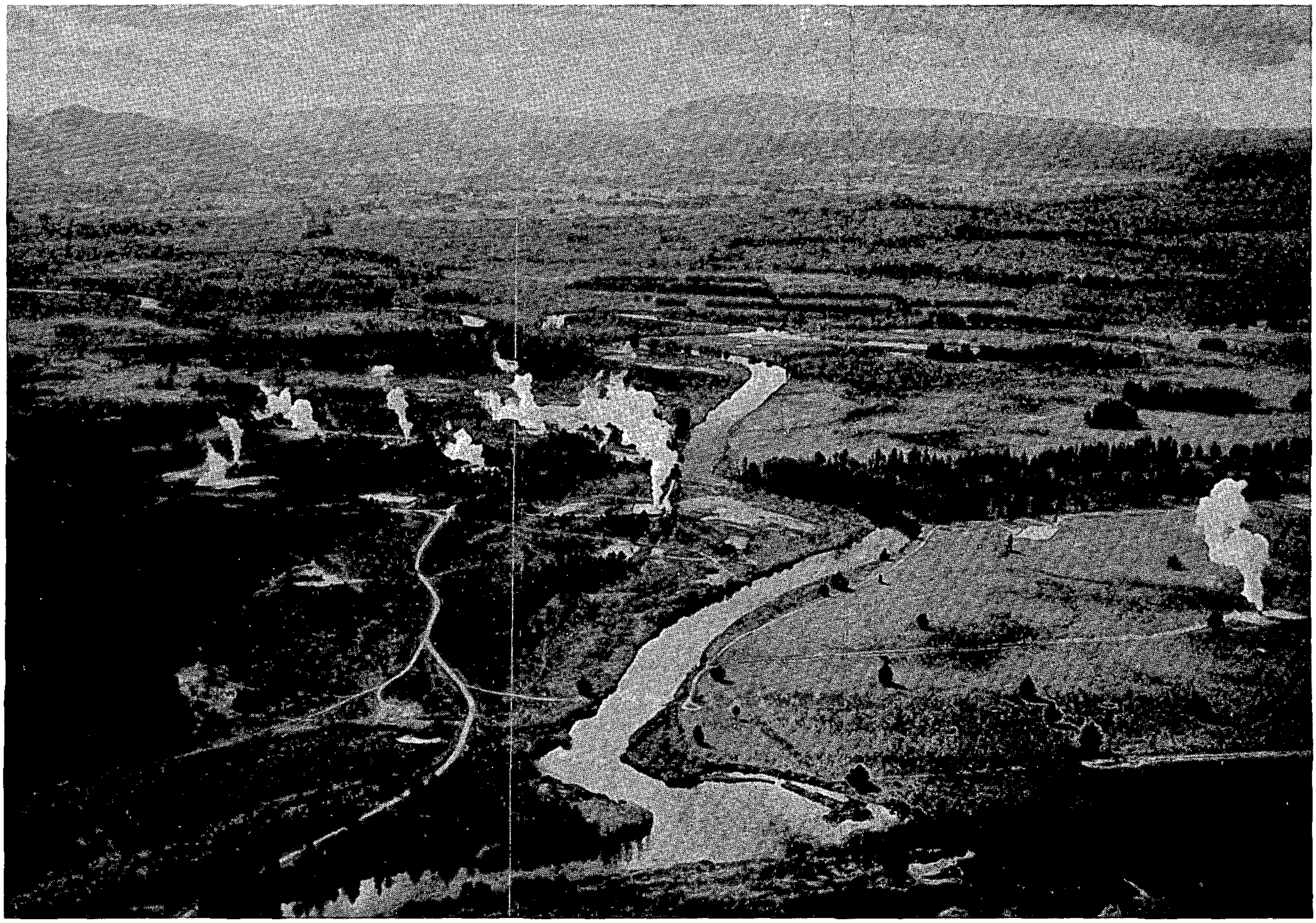

Fig. 24. Broadlands geothermal field in New Zealand — 1972 (courtesy of Richard S. Bolton, New Zealand Ministry of Works and Development)

however, is $11,860,000. To this stage, the overall success rate is one-in-twenty. Neglecting tax benefits, this figure gives the risk burden for investment to this point in the exploration venture.

Beyond the need for 20% return on expenditures, no special risk factors are applied to the step-out wells and testing. If greater uncertainty exists at this stage, expected statistical costs may be significantly greater. As calculated, total investment in the discovered field is $2,232,500. Overall costs leading to the discovery are $13,822,000. Therefore the success rate for investment in exploration through step-out wells is just under one-in-six.

Leasing. The importance of land costs in the overall expenditure for exploration should be noted. Fairly early in the evaluation of lands, control of the geothermal interests is secured. Without such control, the property and, consequently, the investment in exploration may be lost to another party.

The cost of the geothermal property interests also increases as exploration progressively proves the land's potential. Early control of a promising area is therefore encouraged. This effect can be seen in bonus bids for federal resource acreage. Following the discovery of oil at Prudhoe Bay in Alaska, for example, lease bonuses on surrounding land jumped from $9/acre to almost $2,200/acre.[10] (Fig. 26)

Exploration Method	Cost/Tract	No. of Tracts	Risk-Weighted Cost
Geology & Geophysics	$ 40,000	64	$ 2,560,000
Land Acquisition ($7/acre)	$ 52,500	32	$ 1,680,000
Additional Geophysics	$ 15,000	32	$ 480,000
Temperature Holes	$ 40,000	24	$ 960,000
Test Well to 5000 ft			
a) bore	$ 365,000	16	$ 5,840,000
b) casing	$ 85,000	4	$ 340,000
Subtotal	$ 597,500		$11,860,000
Three Step-out wells	$1,095,000	1	$ 1,314,000
Testing Operations	$ 540,000	1	$ 648,000
Total	$2,232,500		$13,822,000

Fig. 25. Schedule of probable successes and statistical costs in exploration (from Greider, "Status of Economics," figure 9)

Date of Sale	Acres Leased	$/Acre	Bonuses Paid
Dec. 9, 1964	466,180	$ 9	$ 4,376,523
July 15, 1965	403,000	15	6,145,473
Jan. 24, 1967	37,662	39	1,469,645
Sept. 10, 1969	412,548	2182	900,218,590

Fig. 26. Results of Alaska North Slope lease sales before and after 1968 Prudhoe Bay discovery (Reprinted with permission of Ballinger Publishing Company from *Studies in Energy Tax Policy*, Copyright 1974, The Ford Foundation)

A similar range of costs has occurred in The Geysers area of California for geothermal leases. Bonus bids have been as high as $1,200/acre, while outside the well-explored areas, bids of only a few dollars per acre have taken the lease.[11]

Property investments are strongly affected by risk. The table of probable successes (Fig. 25) shows one influence of uncertainty. It is estimated that of 32 tracts leased, on the average only one will be productive. At $7/acre, this investment is the third largest component of exploration costs, and its weight may force small exploration companies to forgo all but the least costly (promising) lands.[12]

Uncertainty in locating and sizing a prospective reservoir also influences property investment by forcing the explorer to lease large tracts. From Figure 27 it is seen that a well flow of 40 kg/s (480,000 lbs/hr) from a 260°C reservoir will support 5 MW of power. At 40-acre spacing with back-up wells, a 200 MW field will occupy 2000 acres.[13]

Temperature, well flow rates and well spacing determine the minimum area necessary to generate 1 MW of power. These factors vary considerably between reservoirs, but for purposes of discussion, we take 10-15 acres/MW as typical.

In Figure 28 a 200 MW field (9-10 km²) is placed within a parcel of 7500 acres (30 km²). As seen, there is little room for error in locating the field center or estimating its total size. In the "best case" (A), no more than a 50% error in location (1.5 km) is permissible. Under less optimum conditions (B), an error of 50% (2.5 km) could place 40% of the resource outside the 7500 tract.

Location of the reservoir may in fact be subject to great error. At Ahuachapan, Salvador, the thermal center of the reservoir is 7 km from the nearest surface discharge. At Kizildere, Turkey, the thermal center is 5 km from the up-flow center. Deflection of convecting water in these two systems results from lithologic barriers. In other instances, groundwater may mask and deflect thermal discharge many kilometers from the source.[14]

Estimation of reservoir size also is subject to wide error. This problem was encountered earlier when reviewing the U.S.G.S. assessment of geothermal resources. Order-of-magnitude differences were noted there.

To compensate for such uncertainty in placement and sizing of a prospective reservoir *without extensive exploration*, large areas of land must be leased. The effect on statistical investment is considerable. Tracts of 15,000 acres, rather than 7500 acres, would require an overall exploration budget increase of 13%.

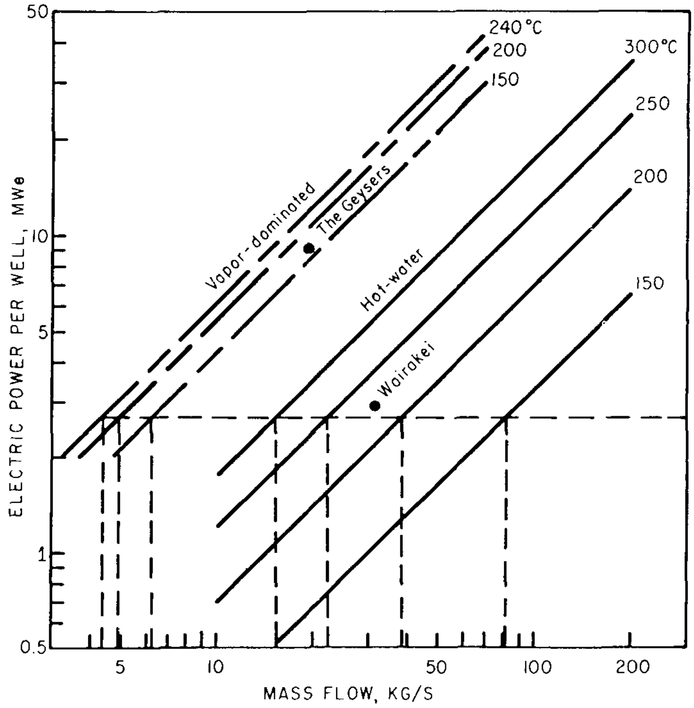

Fig. 27. Electric power as a function of mass flow for various temperatures of hot-water and vapor-dominated reservoirs (from Nathenson and Muffler, "Geothermal Resources," p.116)

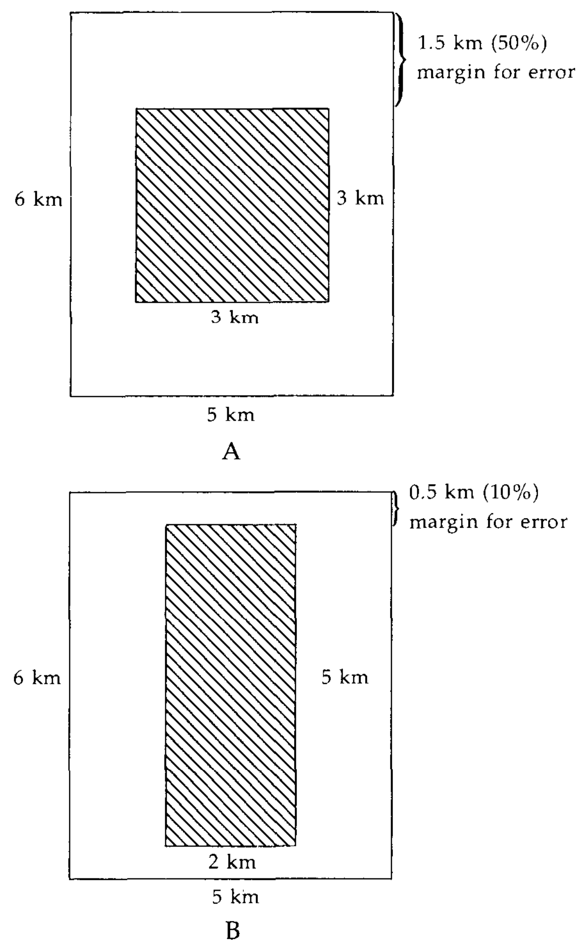

Fig. 28. Locating a 200 MW field (9-10 km²) within 7500 acres (30 km²)

It should be noted that lease acreage limitations, such as the federal maximum of 20,480 acres/state, work to prevent numerous holdings of the required size. Also because of the uncertainty and large acreage involved, cash bonus bidding for leases tends to exclude geothermal developers with limited budgets. These issues are taken up again in the discussion of lease provisions in Chapter 5.

Geothermal exploration is a relatively new endeavor. Consequently, risk estimates are rather personal items. Not all workers in the field concur with those given above. Figure 29 compares other estimates that have appeared in the literature; more than a factor of three separates the high and low estimates.[15]

Exploration Phase	Cost	Success Rate	Present Value
Geophysical	$ 95,000	18%	$ 531,000
		2%	$ 4,000,000
Exploratory Well	$ 450,000	40%	$ 1,125,000
		16%	$ 2,889,000
		7%	$ 6,180,000
Subtotal	$ 545,000	33%	$ 1,656,000
		16%	$ 3,420,000
		5%	$10,180,000
Three Step-out Wells	$1,350,000	80-85%	$ 1,590,000 to $ 1,690,000
		66%	$ 2,025,000
Testing	$ 540,000	15% return	$ 621,000
Total	$2,435,000	61-63%	$3.9-$4.0 million
		40-42%	$6.1-$5.8 million
		19%	$12.5 million

Fig. 29. Estimates of exploration success rates

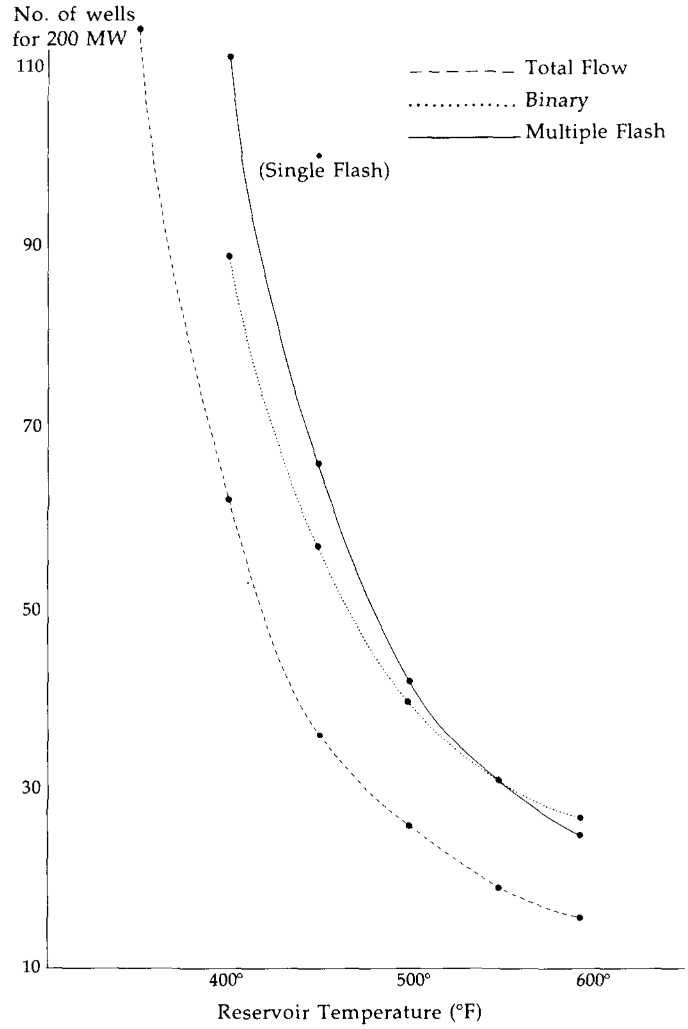

Fig. 30. Wells to supply 200 MW as a function of reservoir temperature

RESERVOIR DEVELOPMENT

Various combinations of temperature, depth, fluid quality, productivity and longevity may yield a commercially producible geothermal reservoir. A moderate-temperature, near-surface reservoir, for example, may be as attractive for development as a higher temperature reservoir that is more saline or lies at greater depth.

A reservoir is suitable for power production, though, only if the developed fluid can be economically matched to an electric generation facility. Therefore unlike petroleum and other mining operations, field engineering and powerplant design are fused into a comprehensive reservoir development program.

Field Development Costs

Fluid Temperature. Other things equal, the cost of producing geothermal electric power declines with increasing fluid temperature. Both the heat value (enthalpy) of the fluid and the efficiency of electric conversion are greater at higher temperatures. In addition, high-temperature wells tend to produce fluid at a greater rate than low-temperature wells. Consequently, less fluid is required to generate the same amount of power, and fewer wells are needed to supply the fluid.

The importance of temperature can be seen in Figure 30, which graphs according to temperature the number of wells required to generate 200 MW of power.[16] The cumulative effects of reduced fluid enthalpy, conversion efficiency and well production at lower temperatures result in an exponential increase in supply wells (see Fig. 44).

Plant costs also are lower for high-temperature reservoirs. Smaller flow rates involve smaller piping, turbines and heat exchangers, while increased plant efficiency permits smaller capacity cooling systems. These components constitute major capital expenses in geothermal plants.[17]

Reservoir permeability. The rate at which fluid can be produced from geothermal wells depends on aquifer permeability. The effect of permeability on power costs can be inferred from Figure 31, which plots required supply wells for a 200 MW plant as a function of well (mass) flow rate.[18]

Well depth. Drilling costs increase dramatically with depth. It is this fact which makes most of the earth's immense heat inaccessible. The exact amount spent to drill a well varies with site and formation character.

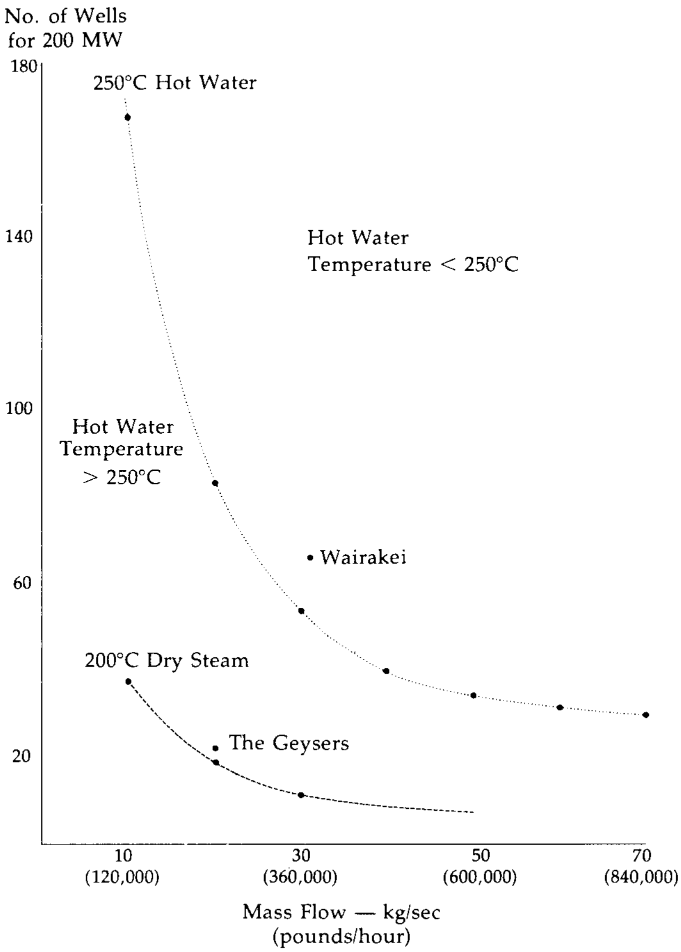

Fig. 31. Wells to supply 200 MW as a function of flow-rate

Depth (km)	Total Cost	Average Cost/meter	Marginal Cost/meter	Source
0.5	$50,000	$100	$100	Meidav
1.0	$150,000	$150	$200	Meidav
	$150,000	$150		U.S.G.S.
2.0	$420,000	$210	$270	Meidav
	$300,000	$150	$150	U.S.G.S.
	$300,000-$520,000	$166-$216		Rex
3.0	$810,000	$270	$390	Meidav
	$500,000	$167	$200	U.S.G.S.
	$425,000-$770,000	$170-$260	$250	Rex
5.0	$1,000,000	$200	$250	U.S.G.S.
	$635,000-$1,055,000	$200-$230	$250	Rex
10	$5,000,000	$500	$800	U.S.G.S.
	$2,750,000	$300	$340	Rex

Fig. 32. Drilling costs for geothermal wells

Average costs are revealing, however, and several estimates appear in Figure 32.[19]

While deeper holes are more expensive to drill, they generally produce higher temperature fluids. Savings associated with higher fluid temperatures must therefore be weighed against higher drilling costs.[20]

Field Development Risk

Success in drilling development wells is not guaranteed even though a producible reservoir has been discovered. As previously noted, aquifer permeability is not uniform throughout a geothermal reservoir. Wells may fail to encounter a sufficiently permeable, productive region within a generally strong reservoir.

Different estimates of success ratios for development drilling have appeared in the literature, ranging from 66% to 90%. (Fig. 29) The rate of success will necessarily depend on the character of the producing formation, but using these figures, the statistical investment in development wells may be obtained.

If 50 production wells are needed, a 66% success ratio implies that a total of 75 wells will be drilled; with 90% success, 56 wells will be drilled.

Using $500,000 as the cost for completed wells and $400,000 for unsuccessful wells (no production casing, etc.), the following expenditures result:

TOTAL WELLS	TOTAL COST	DIFFERENCE
75	$35,000,000	$7,600,000
56	$27,400,000	

At a 20% return on investment, the difference in well costs would be $1,520,000 per year. This calculation assumes, however, that unsuccessful development wells have no value. Actually this may not be true. A supply well failure may be a very useful disposal well. Power-plant effluent generally must be eliminated by returning it to subsurface strata. For water-dominated reservoirs, each supply well needs an injection well for disposal. Drilling risk is therefore reduced by the fraction of unsuccessful wells which are valuable for other purposes. On the other hand, any estimate of field development costs should include expenditures for injection wells.

Reservoir and Well Lifetimes

Performance of geothermal wells and reservoirs over time is a major uncertainty in geothermal development. Geothermal well-life varies between 10 and 20 years according to the nature of the fluid and its rates of production and recharge;[21] these same factors affect the lifetime of the reservoir.[22]

Short lifetime or uncertainty about production longevity induces rapid amortization of capital. Any requirement for rapid amortization strongly affects the cost of power.

The annual returns on exploration investment in a 200 MW field calculated for amortization periods of 10 and 20 years appear in Figure 33. The present value of return corresponds to the statistical investment in exploration previously calculated (Fig. 29). A 10% discount factor was used.

Present Value	Annual Return (10 yr)	Annual Return (20 yr)
$4 million	$656,000 = 0.47 mills/kwh	$471,000 = 0.34 mills/kwh
$6 million	$984,000 = 0.7 mills/kwh	$706,000 = 0.5 mills/kwh
$12 million	$1,967,000 = 1.4 mills/kwh	$1,412,000 = 1.0 mills/kwh

Fig. 33. Amortization of exploration costs for 200 MW field

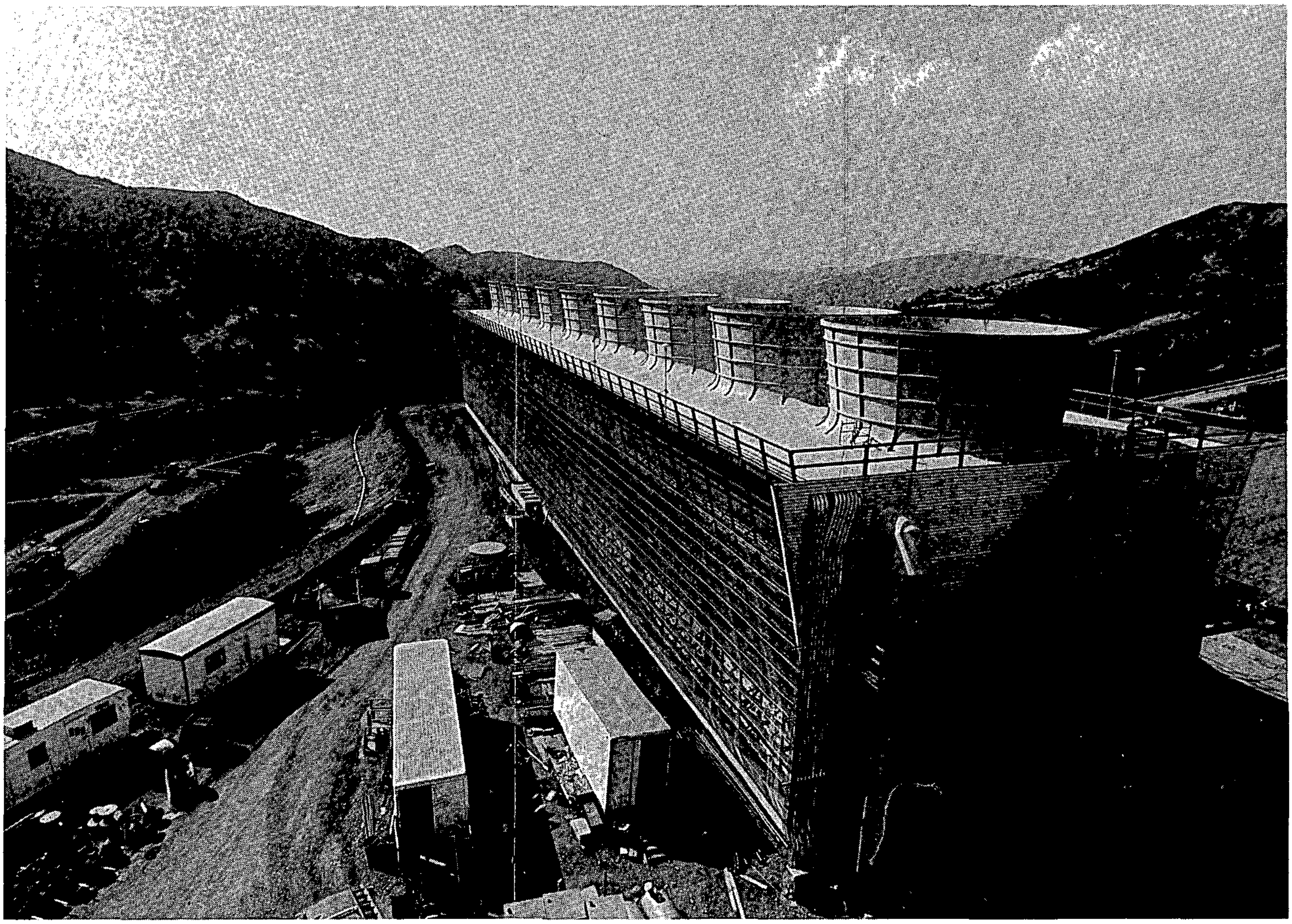

Fig. 34. Power Plant Unit 11 (106 MW) at The Geysers (courtesy of Pacific Gas and Electric Company)

The calculation reveals the strong impact of a short amortization period. Amortization of any investment over 10 years rather than 20 years with a 10% discount rate increases the required annual return by almost 40% (see Fig. 44).

POWERPLANT DEVELOPMENT

Plant design for a particular geothermal reservoir is selected according to the character of its fluid. Dry-steam reservoirs, like The Geysers, produce steam that may be used almost directly in relatively inexpensive turbines (Fig. 34). For water-dominated reservoirs, plant design is dictated by fluid temperature, mineral content and the quantity of dissolved non-condensible gases (e.g., CO_2, H_2S).

Local water supply, meteorological conditions and environmental sensitivities also affect plant selection. Cooling and make-up water requirements differ between designs, and discharges to the environment vary between them.[23]

Three basic design options have been advanced for water-dominated reservoirs. These are the flashed steam, binary fluid and total flow systems.

Flashed Steam Plant

The boiling point of water increases with depth due to hydrostatic pressure (Fig. 10). If fluid pressure is allowed to drop at that temperature, a portion of the fluid will flash to steam. The amount of steam produced depends on the original temperature and the pressure decrease.

When geothermal fluid is withdrawn without maintaining the reservoir pressure, some of the fluid flashes to steam. A flashed steam plant employs this steam, and the remaining fluid is discarded. As seen in Figure 35, a large percentage of fluid heat value is lost with the discharge.

The flashed steam plant is attractive despite considerable waste of fluid heat value because it employs simple and relative inexpensive steam turbines. Installed plant cost is approximately \$200/kw.[24] Improved recovery of fluid heat can also be achieved through multiple-flash stages. In general, multiple-flash design is preferred because of savings in supply wells and other field development costs, even though it significantly increases plant complexity and cost.

For fluids high in minerals or non-condensible gases, however, flashed steam plants may be impractical.

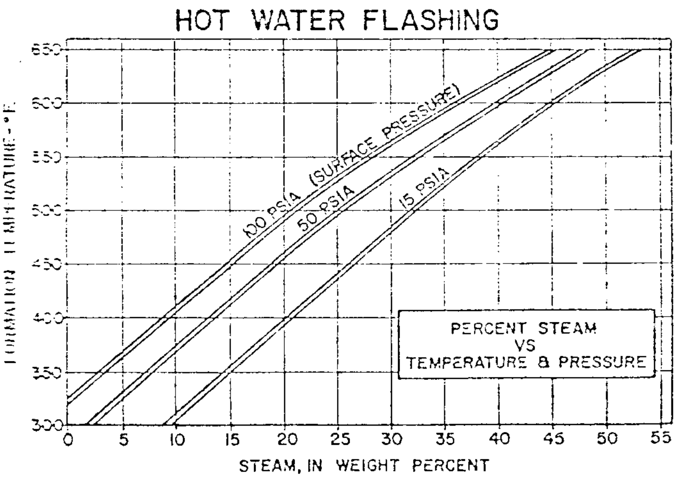

Fig. 35. Percentage of hot water flashing to steam as a function of temperature and pressure (from Greider, "Status of Economics")

Flashing results in deposition of the solids, and non-condensible gases greatly reduce net power production from steam turbines (Fig. 36).[25] Non-condensible gases may also create environmental problems. When released from the fluid stream through flashing, they are discharged to the atmosphere.[26] Hydrogen sulfide (H_2S) is one such gas which in small quantities is both poisonous and extremely noxious in odor.

A flashed steam plant may also be unattractive for moderate-temperature reservoirs. Steam yield from such fluids is very low, and the consequent increase in supply well costs becomes prohibitive. Under these conditions, alternative design options may be preferred.

Binary Fluid Plant

A binary fluid plant utilizes a heat exchanger to transfer heat from the produced geothermal fluid to a secondary fluid. The secondary fluid (e.g., Freon, isobutane) is chosen to have a boiling point significantly below the temperature of the produced fluid. In this way, the secondary fluid is vaporized and used to drive a turbine. Capital cost estimates for binary plants range from \$300/kw to \$500/kw.[27]

The binary cycle has several attractive features compared to the flashed steam plant. In the first place, the system can be tailored to the temperature of the geothermal fluid to capture a larger percentage of the fluid's heat value. This advantage is especially marked at temperatures less than 200°C.[28]

The binary cycle is able to utilize saline brines. This is an important strength. Two types of scaling occur in geothermal systems. Some deposition results when the temperature of the fluid is reduced. Silica scaling is of this type and is common to all geothermal plants for water-dominated reservoirs. Its severity depends on the solids content of the fluid.

The second type of scaling results when fluid pressure is reduced. Deposition of calcium carbonates, for example, results from pressure reduction.[29] Pressure drop also causes silica deposition. With binary cycles, the geothermal fluid pressure can be maintained, using pumps to circulate the fluid from supply wells, to the

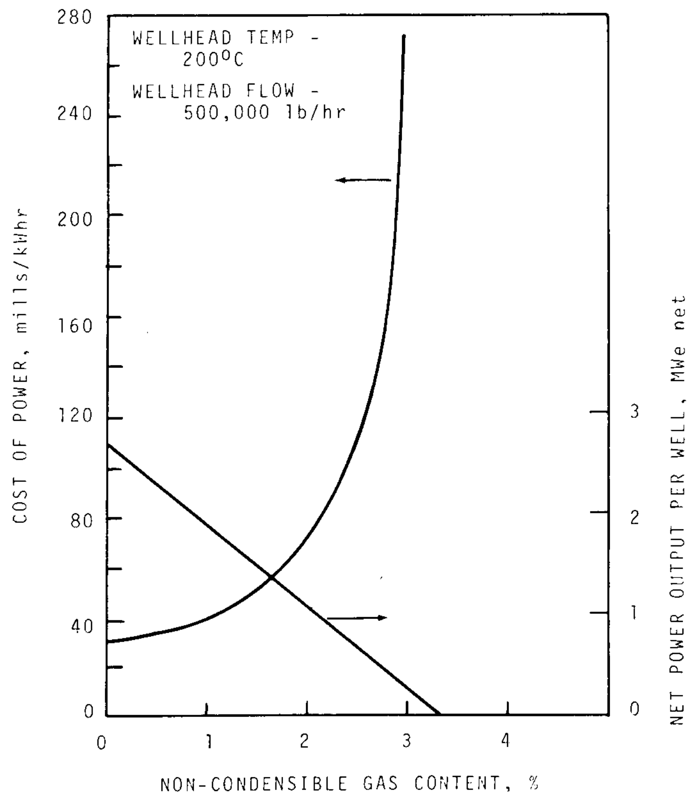

Fig. 36. Effect of noncondensible gases on net power output and cost (from Bloomster and Knutsen, "Economics of Geothermal Electricity," figure 15)

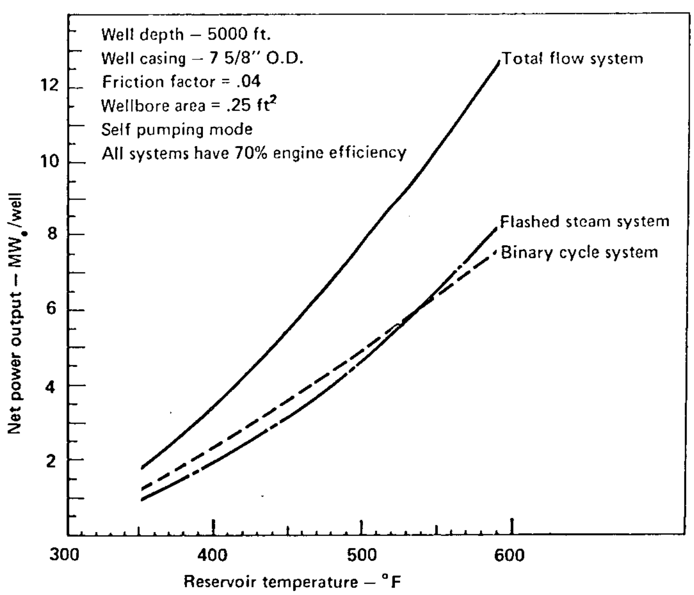

Fig. 37. Comparison of geothermal power systems (from Austin, "Total Flow Concept," figure 2)

heat exchangers and back into the reservoir through injection wells. Part of the plant's electrical output must be consumed to power the pumps, but in this way some serious scaling problems are avoided and others considerably reduced.

Case	Surface Technology	Wellhead Temp.(°C)	Well Flow Rate (10^3 lb/hr)	Cost Per Well ($1,000)	Plant Size (MWe) Gross	Plant Size (MWe) Net	Total Cost of Power (Mills/kw-hr)
A-s	Steam: 2 Plant Flash	250	750	500	55	53.0	17.2
A-b	Binary/ Isobutane	250	750	500	55	46.1	19.5
B	Binary/ Isobutane	200	500	500	55	44.5	28.2
C	Binary/ Isobutane	150	250	500	55	45.9	85.3

Fig. 38. Power costs for representative hot-water reservoirs (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 2)

Unlike flashed steam plants, binary fluid plants are not affected by the non-condensible gas content of geothermal fluids.[30] Electric conversion is not impaired, and noxious gases such as hydrogen sulfide are not allowed to degrade local air quality. The entire fluid stream is totally confined and returned to the reservoir.

Total Flow Plant

Electric conversion in the total flow plant employs all of the produced fluid with a specially designed nozzle and turbine. One proposed design uses a helical screw which rotates as the fluid expands along its axis.[31] Another type is designed somewhat like a waterwheel.[32] Both types have design efficiencies greater than binary or multiple flashed steam cycles. Figure 37 compares the efficiencies of flashed steam and binary cycles to the Lawrence Livermore Laboratories helical screw expander.

While steam turbines and binary fluid heat converters are well-known and tested technologies, the total flow systems are as yet unproven designs. Whether theoretical efficiencies can be attained in practice at reasonable costs is still to be demonstrated. Scaling and the release of non-condensible gases are problems this design shares with flashed steam systems.[33]

GEOTHERMAL POWER COSTS

Geothermal reservoirs vary widely in character, and calculations of geothermal power costs must be based on a number of assumptions. These may or may not be true for a particular reservoir. Representative calculations may nevertheless be performed and the results compared when assumptions are modified. Economic studies of this kind have been performed at Battelle Pacific Northwest Laboratories and at Lawrence Livermore Laboratories.[34] The following discussion is based on their results.

Hydrothermal Systems

The cost of electricity computed for three low-salinity, water-dominated reservoirs are shown in Figure 38. Wells in each case are assumed to have a 10-year life and to cost $500,000. The financing and tax assumptions listed in Figure 39 also hold for each case. With these assumptions, only the reservoir with both low temperature and low flow-rate is not economically viable. A flow-rate of 750,000 lbs/hr (= 1.7 MW/well), as in Case A, and well costs of $250,000 (i.e., shallow reservoir), would make this reservoir much more competitive. Initial capital investment per net kilowatt capacity is shown in Figure 40.

The distribution of powerplant and field development costs given in Figures 41-43 may be used to roughly gauge the relative effects of different well or plant equipment costs on the cost of geothermal power.* The impact of state and federal taxes and a 10% royalty charge on fluid production may also be seen, although income taxes calculated for different power prices (17.2, 28.2 and 85.3 mills/kwh) may be somewhat misleading. Geothermal power is likely to be priced approximately equal to the cost of power from other sources. In that

	Reservoir (%)	Powerplant (%)
Capitalization		
Debt	42	59
Equity	58	41
Bond Interest Rate	8	8
Return on Equity	15	12
Federal Income Tax Rate	48	48
State Income Tax Rate	7	7
Property Tax Rate	2.5	2.5
Royalty Payment	- 10	....
Revenue Tax Rate	....	4

Fig. 39. Financing and tax assumptions for hot-water reservoirs (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 1)

Case	Reservoir	Powerplant	Total
A-s	102	291	393
A-b	110	329	439
B	189	335	529
C	738	375	1113

Fig. 40. Initial capital investment ($/kWe net) (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 7)

*Exploration costs calculated earlier (Figs. 29 & 33) for a 200 MW field ranged from 0.34 mills/kwh to 1.4 mills/kwh, depending on the amortization rate and assumed risk. The 0.7 mills/kwh exploration cost assumed in the Battelle study falls, therefore, at the middle of this range.

	Case A-s (mills/kwh)	Case B (mills/kwh)	Case C (mills/kwh)
Powerplant			
Capital	7.1 (41.3%)	8.2 (29.1%)	9.2 (10.8%)
Operating Expenses	.3 (1.7%)	.4 (1.4%)	.4 (.46%)
Energy Supply	9.8 (57.0%)	19.7 (69.9%)	75.7 (88.7%)
Total	17.2	28.2	85.3

Fig. 41. Distribution of total power costs (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 3)

	Case A-s (mills/kwh)	Fraction of Total Power Cost	Case B (mills/kwh)	Fraction of Total Power Cost	Case C (mills/kwh)	Fraction of Total Power Cost
Initial Plant Capital	4.5	26.2%	5.1	18.1%	5.7	6.7%
Interim Capital Replacements	.1	.58	.2	.71	.2	.23
Property Taxes and Insurance	1.2	7.0	1.3	4.6	1.5	1.8
State Revenue Taxes	.3	1.7	.3	1.1	.4	.46
State Income Taxes	.1	.58	.2	.71	.2	.23
Federal Income Taxes	.9	5.2	1.1	3.9	1.2	1.4
Total	7.1	41.3%	8.2	29.1%	9.2	10.8%

Fig. 42. Distribution of power costs related to powerplant capital costs (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 4)

		Case A-s (mills/kwh)	Fraction of Total Power Cost		Case B (mills/kwh)	Fraction of Total Power Cost		Case C (mills/kwh)	Fraction of Total Power Cost
Exploration		.7	4.1%		.7	2.5%		.7	0.8%
Field Development		2.8	16.3%		5.0	17.7%		21.1	24.7%
Producing Wells	1.4			2.8			12.4		
Fluid Transmission	.4			.6			2.3		
Fluid Disposal	.8			1.2			4.8		
Non-Producing Wells	.1			.4			1.6		
Field Operation		3.1	18.0%		5.6	19.9%		23.4	27.4%
Producing Wells	.7			1.1			4.0		
Fluid Disposal	0.9			2.1			9.2		
Fluid Transmission	.5			.7			2.8		
Other	1.0			1.8			7.4		
State Income Tax		.1	.58%		.2	.71%		.9	1.1%
Federal Income Tax		.9	5.2%		1.5	5.3%		6.1	7.2%
Royalty Payment		.9	5.2%		1.4	5.0%		5.6	6.6%
Bond Interest		.5	2.9%		.8	2.8%		3.0	3.5%
Subtotal		9.10	52.9%		15.3	54.3%		60.6	71.0%
Charge for Internal Power Consumption		.4	2.3%		3.6	2.8%		12.1	3.5%
Subtotal		9.4	54.7%		18.9	67.0%		72.7	85.2%
Revenue Taxes (4%) Related to Energy Supply		.4	2.3%		.8	2.8%		3.0	3.5%
Total		9.8	57.0%		19.7	69.9%		75.7	88.7%

Totals may not add because of rounding.

Fig. 43. Distribution of energy supply costs (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 6)

Parameter	Reference Value	New Value	% Change in Parameters	% Reduction in Power Cost	New Power Cost (Mills/kW-hr)	Elasticity: % Reduction in Cost of Power Per % Change in Parameter
Wellhead Temperature	200°C	250°C	+ 25	19	22.9	.76
Cost of Capital		(reduced by 1/2)	- 50	31	19.4	.62
Cost per Well	$500,000	$300,000	- 40	20	22.64	.50
Well Flow Rate	500,000 lb/hr	750,000 lb/hr	+ 50	17	23.3	.34
Plant Capital	$14.9 million	$7.5 million	- 50	14	24.1	.28
Internal Power Consumption	10.5 MWe	5.25 MWe	- 50	11	25.2	.22
Taxes	(All tax rates reduced by 1/2)		- 50	10	25.3	.20
Cost of Transmission & Disposal Systems		(reduced by 1/2)	- 50	9	25.6	.18
Reinjection Costs	Reinjection	No Reinjection	-100	16	23.6	.16
Well Life	10 years	20 Years	+100	10	25.3	.10
Excess Producing Wells	20% of Production Wells	5% of Production Wells	- 75	6	26.4	.08
Cooling Tower	Included	Excluded	-100	6	26.5	.06
Operating Expenses		(reduced by 1/2)	- 50	3	27.3	.06
Royalty Payments	10%	0	-100	5	26.7	.05
Dry Wells	20% of Production Wells	5% of Production Wells	- 75	4	27.1	.05
Exploration Costs	Included	Excluded	-100	4	27.1	.04
Plant Life	30 years	40 years	+ 33	1	27.9	.03
Transmission & Disposal Systems Maintenance Rate	.05	.025	- 50	1	27.9	.02
Intangible Write-off	Allowed	Not Allowed	-100	-10**	30.9	-.10**
Plant Life	30 years	20 years	+ 33	- 5**	29.5	-.15**

**Indicates an increase in cost of power

Fig. 44. Results of sensitivity analysis for reference case B with power cost of 28.2 mills/kwh (from Bloomster and Knutsen, "Economics of Geothermal Electricity," table 8)

case, taxes paid on income from reservoirs A and B would be more nearly equal; in fact, higher taxes may be anticipated for more profitable reservoirs.*

In the Battelle study, economic and reservoir assumptions for Case B were altered singly in order to gauge their effects on the cost of power. The results of those calculations appear in Figure 44, which arranges the parameters in the order of their influence on power costs. The large effect on power costs exerted by the cost of capital is noteworthy. Its influence, encountered earlier (Fig. 33), is second only to that of wellhead temperature.

Geopressured Reservoirs

Conditions for development of geothermal resources along the Texas and Louisiana gulf coasts differ from those of the western states. Extensive exploration for oil and gas since the 1920s has supplied abundant information on the area's geology and subsurface formations. Probably over 300,000 wells have been drilled.[35] Therefore in comparison with hydrothermal reservoirs in the western states, location of the geopressured geothermal resource is largely accomplished.

Development of geopressured reservoirs involves complications not found in identified hydrothermal reservoirs. Extraordinary fluid pressure, which is a potentially valuable component of geopressured reservoirs, is an obstacle for drilling and control of the well.[36] The cost per foot to penetrate such formations is correspondingly greater. In addition, most geopressured deposits lie at depths over 10,000 feet — deeper, that is, than any wells presently drilled for hydrothermal resources.[37] Drilling costs are high. A 14,000 foot on-shore well may be expected to cost up to $2.6 million, or more than five times the expected cost for steam and hot water wells in the western states.[38] (Figs. 45 & 53)

At temperatures between 90°C and 150°C (200°-300°F), heat is not the preeminent value of geopressured reservoirs. Electric conversion at these temperatures is

Well Diameter (inches)	Dry Hole	Completed
	Depth 14,000 feet	
4.5	$1,067,000	$1,681,300
5.5	$1,067,000	$1,733,300
7.0	$1,149,000	$1,925,300
	Depth 16,000 feet	
4.5	$1,622,700	$2,287,700
5.5	$1,622,700	$2,346,400
7.0	$2,220,500	$3,077,000
	Depth 18,000 feet	
4.5	$1,895,200	$2,595,200
5.5	$1,895,200	$2,662,700
7.0	$2,548,700	$3,468,200

Fig. 45. Well costs for geopressured reservoirs (from Podio et al., "Plan for Geopressured Geothermal Well," p.24)

*This may be less true in case percentage depletion with a net income limitation is extended to geothermal development. See discussion of the federal income tax.

	Depth (ft)	Area (sq mi)	Pressure (psi)	Well Depth (ft)	Temperature	Methane
Zone I	5,000-10,000	22,500	5,100	8,500	200°F	19 scf/bbl
Zone II	10,000-15,000	30,600	9,100	13,000	250°F	30 scf/bbl
Zone III	15,000-20,000	5,700	12,800	16,000	300°F	44 scf/bbl

Fig. 46. Characteristics of gulf coast geopressured reservoirs (from House, Johnson and Towse, "Potential Power Generation," p.285)

Zone	Disposal Method	Wellhead Pressure (psi)	Well Flowrate (10^3 bbl/day)	Net Electric Output (kw)	Gas Production (mcf/day)	Annual Gross Income		Percent of Income	
						Electric*	Gas*	Electric*	Gas*
I	Injection	1,150	30.3	359	555	$ 75,390	$ 324,120	19%	81%
I	Surface	700	47.9	748	877	$ 157,080	$ 512,168	23%	77%
II	Injection	2,400	54.6	1,974	1,571	$ 414,540	$ 917,464	31%	69%
II	Surface	1,800	66.4	2,794	1,909	$ 586,740	$1,114,856	34%	66%
III	Injection	3,600	74.5	4,952	3,025	$1,039,920	$1,766,600	37%	63%
III	Surface	2,800	84.9	6,178	3,446	$1,297,380	$2,012,464	39%	61%

*For electricity priced at 30 mills/kwh and natural gas at $2/mcf

Fig. 47. Well productivity for geopressured zones (from House, Johnson and Towse, "Potential Power Generation," table 2)

relatively inefficient, and high fluid flow involves large costs for supply and (possibly) disposal wells. Fluid pressure and dissolved methane gas predominate in geopressured reservoirs. This fact is apparent from the study of development economics performed at Lawrence Livermore Laboratories.

The LLL study divided geopressured deposits between 5000 feet and 20,000 feet into three zones according to depth. The present maximum depth of well control is about 20,000 feet, and geopressured deposits below that level were not considered in the LLL study. Physical characteristics for the three zones are listed in Figure 46.

The productivity of wells penetrating the geopressured zones was calculated for two wellhead pressures. With injection of produced fluids, wellhead pressure must be higher, and fluid production is correspondingly reduced. Well productivity for the three zones is shown in Figure 47, where net electric output combines thermal and hydraulic conversion. At higher wellhead pressures and lower fluid production, hydraulic power accounts for a larger percentage of electric output. For zone III, about 40% of power generation comes from conversion of fluid pressure.[39]

Figure 47 also indicates gross income and the fraction of total income supplied by electrical and natural gas production if wells produce 80% of the indicated capacity. Sales prices were assumed to be $2/mcf for natural gas and 30 mills/kwh for electric power, which are commensurate with oil priced at $10/barrel.[40]

Electrical output is low from the shallower, cooler zones. Even from zone III, electric power sales provide only 39% of total gross income, with the thermal component supplying at most 25% of total income. At the same time, plant costs for thermal conversion can be expected to exceed methane separation and hydraulic conversion equipment. The LLL study concluded that electric generation facilities for zone I were not economically feasible at $2/mcf and 30 mills/kwh. Zone II reservoirs were found marginally feasible in case fluid injection was unnecessary. Results of their analysis for zone III reservoirs are shown in Figures 48 & 49, where 15% is taken as the minimum feasible internal rate of return after tax. Without methane production, electric generation from zone III would only be marginally feasible at 40 mills/kwh without injection, or 63 mills/kwh with injection.

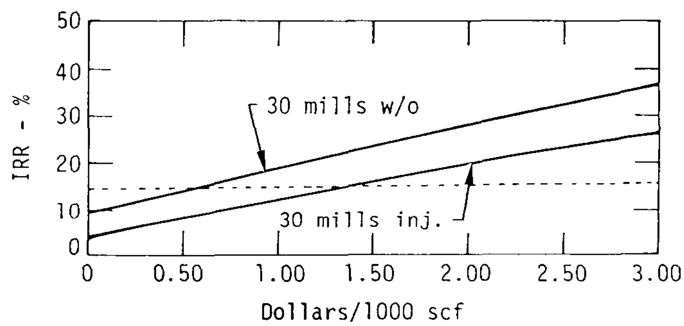

Fig. 48. Internal rate of return for 300°F Zone III reservoir for electricity plus gas (from House, Johnson and Towse, "Potential Power Generation," figure 8)

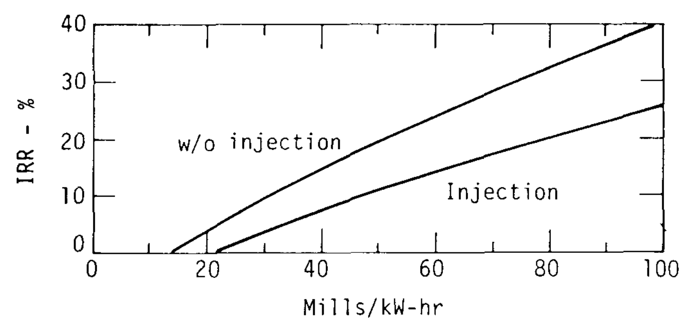

Fig. 49. Internal rate of return for 300°F Zone III reservoir for electricity only (from House, Johnson and Towse, "Potential Power Generation," figure 9)

GEOTHERMAL INVESTMENT AND MARKETING

Magnitude of Investment

To discover and develop 100,000 MW of geothermal power from hydrothermal convection reservoirs — capacity reasonably expected to be accessible with present technology at near-present costs — large amounts of investment capital must be available. Field exploration, development and powerplants will cost over $75 billion.

If $13 million is the statistical cost to discover 200 MW of capacity, $0.65 billion will be required to prove the fields. To supply the powerplants, 30,000 wells of 4 MW will be needed, including 20% reserve capacity. A comparable number of injection wells will probably also be needed. With well-costs of $500,000, $15 billion will be needed for supply and approximately $15 billion for injection wells. Pipelines will cost about $5 billion.

Since most hydrothermal reservoirs are water dominated, powerplant costs should range between $300/kw and $500/kw. At $400/kw, plant costs will be $40 billion.

The cost of transmission lines for geothermal fields will vary considerably according to distance from load centers and from established powerlines. If 20 miles of new installation are required on the average for each 200 MW, line installation will cost $2 billion.[41]

Total investment in 100,000 MW of geothermal capacity will therefore approximate $78 billion, without escalation for inflation. (Fig. 50)

Investment	100,000 MW	200 MW
Exploration and Leasing	$ 0.65 billion	$ 1.3 million
Supply Wells	$15 billion	$30 million
Injection Wells	$15 billion	$30 million
Pipelines	$ 5 billion	$10 million
Powerplants	$40 billion	$80 million
Transmission Lines	$ 2 billion	$ 4 million
Total	$77.65 billion	$155.3 million

Fig. 50. Capital costs for geothermal development

The Project Independence Report estimates that 23% of U.S business investments for 1975-1985 will be used for capital development in the energy sector.[42] This amounts to $420 billion over a decade, with $217 to $271 billion invested in generating plants and transmission lines.[43] Drilling for oil and gas is projected to cost between $50 billion and $100 billion during this same period. Over 35,000 wells will be drilled annually.[44]

To realize its potential as an energy alternative, it is clear that geothermal exploration, field development and plant construction must successfully compete with petroleum, coal and nuclear power projects in the capital market. The geothermal industry now lags far behind. For every geothermal exploration well drilled, 600 are drilled for oil and gas.[45]

Stimulating Investment

The availability and cost of capital will be limiting conditions for large-scale development of geothermal resources. Inherent uncertainty and delays in geothermal development discourage investment and increase the opportunity costs of capital. This fact can be moderated or accentuated by federal and state policies.

A federal policy to promote geothermal development was established by the Geothermal Energy Research, Development, and Demonstration Act of 1974 (P.L. 93-410). (See Appendix 5) Title II of the act initiated a loan guaranty program for geothermal operations, including:

1) the determination and evaluation of the resource base;
2) research and development with respect to extraction and utilization technologies;
3) acquiring rights in geothermal resources; or
4) development, construction, and operation of facilities for the demonstration or commercial production of energy from geothermal resources.

The loan guaranty program was implemented by the Energy Research and Development Administration (ERDA) in June 1976. Regulations for administering loans (10 CFR Ch. III Part 790) were published in the *Federal Register* and are reproduced here as Appendix 6.

The act limits geothermal loan guaranties to at most 75% of a project's aggregate cost. In addition, guaranties may not exceed $25 million for any single project or $50 million for any single borrower. Under the ERDA regulations, the various phases of geothermal development, from exploration and leasing to the construction of powerlines, may be treated as separate "projects." As seen from Figure 50, loan guaranties of $50 million could underwrite approximately 75% of exploration and field development, or 60% of generating plant and powerline costs, for a 200 MW reservoir. Since field development and the construction of electric facilities may generally be undertaken by separate borrowers, $50 million in guaranteed loans to each would seem adequate to finance about 70% of a single 200 MW commercial development.

Loan guaranties could be especially effective in stimulating investment in the exploration phase of geothermal development.[46] As discussed earlier, geothermal exploration involves high risk, and this makes normal financing difficult. At the same time, capital requirements for individual exploration ventures fall within the $25 million and $50 million limits for guaranties. The regulations formulated by ERDA do not, however, give exploration an equal status with other loan applications. Exploration and leasing in fact are given the lowest priority of consideration.[47]

The small size of guaranties available to geothermal developers, the low priority given to exploration, and other limitations in the current loan guaranty program circumscribe its effectiveness.[48] Nevertheless it provides a valuable precedent of support which may be expanded. Direct grants and larger loan guaranties for research, exploration and powerplant construction will be important for large-scale development during the next two decades. In addition, tax policies, securities investment rulings, and utility commission regulations are needed which create a financial atmosphere favorable to geothermal development.

Tax benefits. Petroleum, coal and uranium mining industries have been allowed deductions from taxable income under federal and state tax laws for various development expenditures and for resource depletion taken as a percentage of gross income.[49] The importance of these provisions is examined more closely in a later section. We may simply note here that tax allowances significantly reduce the risk and enhance anticipated returns for investment in the established energy industries. These benefits have not been extended to geothermal development. Without them, the geothermal industry cannot expect to compete equally for investment capital.

Securities rulings. Because it is not an established investment opportunity, regulations controlling the sale and purchase of securities may also adversely affect geothermal development. By their rulings, state securities commissions and the federal Securities and Exchange Commission can expand or contract the supply of capital available to geothermal operations.[50]

One important instance for geothermal development pertains to institutional investors. Geothermal development requires large expenditures not only in field development for wells and pipelines to supply the resource, but also for powerplant and transmission facilities to utilize it. No large established market for immediate sale of geothermal resources is ever available. Institutional investors — trust funds, insurance companies, educational institutions — are capable of supporting large investments combined with income delays characteristic of geothermal development. Their participation could strengthen the position of geothermal industries in the capital market. Prospects for institutional investment are generally governed, however, by guidelines for "prudent" investments. The evaluation of geothermal investments given by securities commissions, whether as prudent or otherwise, can consequently have a strong effect on the geothermal industry.[51]

Utility incentives. Utilities are collectively the dominant investor in electric generation facilities. Utility commission regulations control their capital investments and, in this way, may greatly affect geothermal development. Regulations which permitted: inclusion in the rate base of investments for geothermal technology development and demonstration programs; allowances for higher rates of return and accelerated depreciation for geothermal capital investments; and facility siting priorities which favored geothermal applications over competing powerplant applications would help augment geothermal development.[52]

Marketing

The monopoly structure of utility service creates a marketing problem for geothermal resources, in addition to the investment problems. The primary purchaser of geothermal energy is the utility serving the area where the resource is located. Since utilities make commitments for plant construction ten years in advance, a geothermal supplier may need to wait a decade for a contract to build, even in an area with large electric demand. If the particular utility is chary toward this new type of supply, or has special commitments to other power sources, marketing the resource may be impossible for the geothermal developer.[53]

For large coal-fired or nuclear power plants, new transmission lines are sometimes constructed to reach distant, alternate markets. The installation cost is about $150,000 to $200,000 per mile, assuming rights-of-way are secured.[54] Generally this will not be a feasible option for geothermal power.

Geothermal powerplants are constructed in units of 55-110 MW; this is one of the attractions of geothermal power. It reduces the capital formation problems and large opportunity costs typical of massive construction projects. In addition, lead times for construction are cut, allowing capacity to be more accurately matched to electric demand than is possible with 1000 MW, ten-year coal or nuclear expansions.

But power transmission is a problem. A 100-200 MW plant will not justify long powerline construction. Access to alternate markets will be gained, if at all, through established transmission lines. But these lines generally are owned by private utilities, which may have various reasons to obstruct such access. Without access, geothermal development will be hobbled by the constraints of a strict monopsony market.[55]

Two utility commission policies mandated by the states could help alleviate marketing problems for geothermal power. First, access to transmission lines at reasonable cost could be guaranteed. Second, private producers of geothermal power could be exempted from utility classification if they only market power at the plant to established utilities. In this way, regulatory control over electric power would be maintained, and geothermal power plants could be demonstrated by private parties less averse to risk than utility companies.[56]

Together, policies to expand the available market for geothermal power and to encourage investment in plant construction would be a great boon to geothermal development. Geothermal development is the unknown, relatively speaking, and large-scale development will be achieved only to the extent that state and federal policies seek that end. Encouragement through equitable tax benefits, favorable securities rulings and supportive utility regulations will be necessary if geothermal development is to win a significant share of energy investments.

Notes

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2) Combs and Muffler, "Exploration for Geothermal Resources," p.102.
3) Ibid., pp.107-108.
4) James R. McNitt, "The Role of Geology and Hydrology in Geothermal Exploration," p.39.
5) Ibid.; Greider, "Status of Economics," p.10.
6) Christopher D. Stone and Jack McNamara, *Geothermal Energy and the Law,* Vol.I, p.219.
7) Greider, "Status of Economics," pp.9-11; Figures 7-9.
8) Ibid., p.10.

9) Ibid., pp.10-11; Figure 9.

10) Frederick M. Peterson, "Two Externalities in Petroleum Exploration," pp.101-113.

11) U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975;
Stone and McNamara, *Geothermal Energy and the Law*, pp.83-87.

12) Joseph W. Aidlin, General Counsel, Magma Power Company: Oral Communication.

13) Similar estimates by C. J. Banwell, "Geophysical Methods in Geothermal Exploration," pp.44-46.

14) McNitt, "Geothermal Exploration," p.36.

15) Tsvi Meidav, "Economic Implications of Small Geothermal Power Plants," pp.3-6;
Robert W. Rex and David J. Howell, "Assessment of U.S. Geothermal Resources," pp.65-66.
H. Christopher H. Armstead, "Geothermal Economics," pp.161-174;
Stone and McNamara, *Geothermal Energy and the Law*, pp.54-62.

16) Derived from graph of power output per well as a function of temperature in A. L. Austin, "The Total Flow Concept for Geothermal Energy Conversion," p.191.

17) Clarence H. Bloomster and Cory A. Knutsen, "The Economics of Geothermal Electricity Generation from Hydrothermal Resources," pp.8-9.

18) Derived from Figure 14A, graph of electric power per well as a function of mass flow, in Manuel Nathenson and L. J. P. Muffler, "Geothermal Resources in Hydrothermal Convection Systems and Conduction-Dominated Areas," p.116.

19) Meidav, "Small Power Plants," p.6;
Nathenson and Muffler, "Geothermal Resources," p.114;
Rex and Howell, "Assessment of U.S. Geothermal Resources," p.65.

20) Deeper wells may also encounter strata which produce more fluid. "In one case the productivity of an existing (geothermal) well was increased by 350% simply by deepening it from 952 ft. to 4200 ft." Abt Associates, Inc., *Energy Fuel Mineral Resources of the Public Lands*, Vol. I, p.E6.

21) Futures Group, *A Technology Assessment of Geothermal Energy Resource Development*, pp.31,32,48,54.

22) James Healy, "Geothermal Fields in Zones of Recent Volcanism";
Ping Cheng, "The Effect of Steady Withdrawal of Fluid in Confined Geothermal Reservoirs";
Ronald J. Robinson, "A Study of the Effects of Various Reservoir Parameters on the Performance of Geothermal Reservoirs."

23) Frank P. Witmer, "Choose Your Cycle to Suit Your Well," pp.201-211;
Greider, "Status of Economics," p.16.

24) Greider, "Status of Economics," Figure 16.

25) Bloomster and Knutsen, "Economics of Geothermal Electricity," pp.33-34.

26) See later discussion of environmental protection.

27) Ben Holt and John Brugman, "Investment and Operating Costs of Binary Cycle Geothermal Power Plants," pp.292-301;
Greider, "Status of Economics," Figure 16;
Bloomster and Knutsen, "Economics of Geothermal Electricity," Table 7.

28) Douglas H. Cortez, Ben Holt and A. J. L. Hutchinson, "Advanced Binary Cycles for Geothermal Power Generation," pp.80,86.

29) Ibid., pp.81,92.

30) Ibid., p.82; Bloomster and Knutsen, "Economics of Geothermal Electricity," p.34.

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35) Stavros Papadopulos et al., "Assessment of Onshore Geopressured-Geothermal Resources in the Northern Gulf of Mexico Basin," p.125.

36) Paul H. Jones, "Geothermal and Hydrocarbon Regimes, Northern Gulf of Mexico Basin," p.43.

37) House, Johnson and Towse, "Potential Power Generation," p.285.

38) Augusto L. Podio et al., "Development of Drilling, Completion and Testing Plan for a Geopressured Geothermal Well," pp.9-56; Appendicies I and II.

39) Papadopulos et al., "Geopressured-Geothermal Resources," p.139.

40) House, Johnson and Towse, "Potential Power Generation," p.291.

41) Greider, "Status of Economics," Figure 15.

42) U.S. Federal Energy Administration, *Project Independence Report*, Fig. V-13, p.280.

43) Greider, "Status of Economics," p.23.

44) William Maurer, "Novel Drilling Concepts," p.345;
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45) Ronald C. Barr, Earth Power Corporation: Oral Communication.

46) Samuel M. Eisenstat, Letter to Dr. J. Thomas Ratchford.

47) 10 CFR Ch.III Section 790.4(b).

48) See *Overnight Hearings-Loan Guaranties* for extensive discussion of the loan guaranty program for geothermal resources and of federal loan guaranties in general.

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50) Christopher D. Stone and Joseph W. Aidlin, eds., *Proceedings of the Conference on Geothermal Energy and the Law*, pp.21-22.

51) C. Richard Schuller et al., *Draft of a Report on Legal, Institutional, and Political Problems in Producing Electric Power from Geothermal Resources in California*, pp.122-123.

52) Ibid., pp.75-128; Stone and Aidlin, eds., *Conference on Geothermal Energy*, pp.70-71.

53) Joseph W. Aidlin: Oral Communication.

54) Ibid.

55) Schuller et al., *Draft of a Report*, pp.96-101.

56) Ibid., pp.72-73.

4

Taxation

THE SCOPE OF TAXATION

Several taxes levied on property and income affect resource extraction industries. State corporate franchise taxes, personal and real property taxes, some state sales taxes, state and federal corporate income taxes, severance taxes, and conservation and other special taxes each apply according to the stage of resource development. Corporate franchise and property taxes are effective before income is derived from the resource. The other taxes mentioned, including forms of property taxation, apply to a taxpayer's net or gross income.

Except for franchise and sales taxes, the application of established levies to geothermal development has not been settled. In fact the issues generally have not been broached. Geothermal resources are complex in form, and controversy has surrounded their assignment to any established resource categories (including mineral, water and gas) to which established codes are geared. Several areas of contention involve large financial consequences. Permissible deductions under federal income tax provisions and ad valorem taxation of geothermal property are two notable instances. But whatever determinations may prove final, present uncertainty weighs on the industry. Budgets and cash flows cannot be forecast, and the hovering prospect of litigation undoubtedly chills investor interest.

PROPERTY TAXES

Assessment for taxation of real property bearing natural resources may follow two distinct procedures. The property value may be estimated through "ad valorem" methods—replacement costs of associated equipment, market value of the property, or its estimated income potential capitalized as present worth. Alternatively, property tax may be levied solely on the value of the resource produced, typically the value of income from property during the preceding year. In both cases the value of the resource may be attributed to the surface or, instead, to a separate subsurface estate. Separation is effected, for instance, where the state or federal government has reserved specified minerals, or the entire "minerals" estate, to itself while otherwise conveying property to another party.[1]

In California, ad valorem assessment is performed at the county level. Where cash bonus bids for federal land establish property value, possessory interests are assessed and taxed accordingly. In addition, all geothermal properties may be assessed for income potential when a reservoir is defined and proved through drilling.[2]

The application of ad valorem assessment to geothermal resource properties causes dispute. Concern over this policy arises because long delays occur between the discovery of geothermal resources and their sale for electric generation. Where no powerplant exists to utilize the geothermal fluid, one must be sited, certified and constructed. Where established plants exist, as at The Geysers, permits to drill development wells, construct pipelines and expand plant facilities may involve long review processes in addition to construction lags. Permitting requirements for Unit 12 at The Geysers, a 110 MW expansion, stretched over 42 months.[3]

A tax burden may therefore exist before the resource value can be truly known or utilized, and the financial stress can last for years. Its magnitude may be seen from the calculations in Figure 51. On the basis of potential net income, a 40-acre family holding in a typical geothermal steam field could owe $130,000 per year over and above their accustomed tax liability. For a 200 MW field (720 acres), the tax liability could be over $2.3 million annually.

These figures reveal the pressure of ad valorem property taxation for development of geothermal resources reminiscent of its effect on agricultural lands near urban centers. In both cases, new conditions arise which increase property assessments without actually increasing income from the property.[4] While development of a particular site may be beneficial, the timing of taxation can nonetheless work a hardship. In areas where development of geothermal resources is not an optimum use for the land, the tax burden may nonetheless force abandonment of established, relatively low-income uses.

A special consequence for geothermal development of a property tax threat is discouraged drilling. A large base of geothermal reservoirs defined by drilling would strengthen a geothermal market which presently suffers from uncertainty about supply. With ad valorem taxation, however, the geothermal base would also be a large tax liability promising no income, at least for several years.

On the other hand, the property tax does not discourage land surveys and exploration to the point of drilling, or leasing of land for its prospective value. Surface exploration leaves property values basically unaffected since it cannot demonstrate a reservoir's income value (see Ch. 3). Local land sales or leases *are* generally reflected in ad valorem property values, but as already noted, outside of proven fields the annual rental amounts are small, typically two dollars per acre.

Geothermal properties are not necessarily assessed for ad valorem taxation as calculated in Figure 51. Personal discretion plays a dominant role in ad valorem assessment where recognized standards for judgement are absent. The local assessor may employ different values for the critical variables, or may make various allowances for delays or uncertainty about resource marketing. In The Geysers area, potential income from property beyond wells in place has not generally been assessed for present value.[5]

The discretionary character of ad valorem assessment of geothermal properties may itself be criticized. It adds another uncertainty to geothermal development, and it does not remove the property tax threat. Even as drilling improved utility confidence in geothermal supplies, it may be expected to encourage high valuation of prospective income from geothermal properties.

In summary, the case against a levy on unproduced geothermal resources includes the following points: (1) it forces local assessors to make judgements for which there is insufficient knowledge and experience; (2) it taxes property long before the assessed income value can possibly be realized; (3) it imposes pressure for development irrespective of actual economic, environmental and social values of the development; (4) it militates against investment to prove the capacity of geothermal reservoirs; and (5) it is ineffective in preventing land speculation.

An alternative assessment method based on actual resource production is sometimes advocated by critics of ad valorem. This would avoid the major drawbacks of ad valorem assessment by taxing property only according to realized income. A wellhead tax, which is basically a tax on gross proceeds, has been a standard method of assessment for oil and gas properties in the United States.[6] This type of levy may also be modified to tax property according to net, rather than gross, income. Nevada's net proceeds tax on mineral extraction is an example of this approach.[7]

Within the ad valorem structure, Arizona's provisions concerning property speculation suggest a remedy for the special tax burden felt by geothermal development. The state employs several methods of assessment, including market valuation. To remove the pressure of land speculation on property assessments, the code provides that where market data are used, the amount of property value due to speculation on future income is to be excluded from the appraisal.[8]

As already noted, estimates of future income from geothermal properties are quite speculative. Development is uncertain even though the resource is established. It may therefore be fully appropriate for commercial production alone to demonstrate non-speculative income value for geothermal resource properties.

STATE TAXES ON GROSS RECEIPTS

State gross receipts taxes applicable to extractive industries and public utilities include occupation taxes, sales taxes, severance taxes, and conservation or other special taxes. Franchise taxes based on corporate stock may broadly be included in this category. Property taxes may also be based on gross receipts; this levy has been considered in the preceding section.

Except for California, all states have some form of gross receipts tax which may apply to geothermal operations. The various taxes affect different stages of resource extraction and electric generation, and in some instances, the levies are significant. Hawaii's general excise tax of 4% and its levy of 6% to 8.2% on utility gross receipts are the heaviest, except perhaps for the Texas and Louisiana severance taxes on gas.[9] Methane from geopressured reservoirs may be subject to these levies.

Pacific Gas and Electric presently pays 11.39 mills/kwh for steam supply and disposal at The Geysers. Wells typically are spaced on 20-40 acre lots and generate approximately 8.5 MW each. Anticipated annual income per acre, assuming 30 acre spacing and 80% plant load factor is:

11.39 mills/kwh × 1 well/30 acres × 8500 kw/well × 7000 hrs/year = $22,600/acre/year.

If operating and supply costs are estimated at 30% of sales price (see Fig. 43), then net annual income per acre is $15,820. The present value of this annual income over 20 years, discounted at 10%, is about $134,500/acre ($15,820 × 8.5).

Alternatively, capital costs to supply the steam may be estimated. Robert Greider suggests $29.6 million to supply 200 megawatts of generation capacity. Supply would require about 720 acres, giving $41,100/acre.

Annual income minus replacement costs, using a 5% depreciation factor, equals:

($22,600/acre/year) − ($41,000 × .05) = $20,500/acre/year

The present value of this income over 20 years is $174,250/acre ($20,500 × 8.5). Subtracting capital costs of $41,100/acre yields a net value of approximately $133,200/acre.

These calculations yield approximately the same net present value ($130,000/acre); both are strongly influenced by pricing assumptions (11.39 mills/kwh fixed over 20 years), well-spacing values (30 acres/well), well yield (8.5 MW), estimated equipment life (20 years), and by discounting assumptions for future income.

With an average levy in California of 100 mills and a 25% assessment ratio, the tax encumbered by a present value of $130,000/acre is:

$130,000/acre × 25% × 100 mills/year = $3250/acre/year

Fig. 51. Calculation of property assessment for vapor-dominated geothermal reservoir

It is not really clear, however, which gross receipts taxes apply to geothermal resources. Only New Mexico has specifically made geothermal resources subject to a gross receipts levy—the state's conservation tax—and defined the resource's taxable value.[10]

Severance taxes exemplify the present uncertainty. State severance taxes vary according to the resource under extraction. Major resource industries, such as coal or petroleum, have specific tax rates and methods of assessment. More general mining taxes may also be levied. Idaho, Montana, New Mexico, and Wyoming are states which have established gross receipts taxes on the extraction of 'ores' or 'valuable deposits.'[11]

SEVERANCE TAXES ON GENERAL MINING

Idaho	2.0%	all ores
Montana	0.5%	all minerals, on gross income over $5,000
New Mexico	0.875%	non-metals
Wyoming	2.0%	valuable deposits

It is difficult to say whether these general taxes, or others levied on specific resources such as 'gas', are applicable to geothermal resources. Uncertainty in characterizing the resource confuses any attempt to levy a categorical tax.

In this regard, state definitions of geothermal resources (See Ch. 5) may have important consequences for the application of existing taxes. By their definition of geothermal resources as *sui generis*, "being neither a mineral resource nor a water resource," Idaho, Montana and Washington have undoubtedly obscured the place of geothermal resources under the tax statutes. Wyoming's definition of "hotwater and geothermal steam" as underground waters may exclude them from even the broadest of established severance taxes, since it has not been a practice of Wyoming, or other states, to charge a production tax on water.[12]

There is a need, therefore, that states review their tax policies. Identification of taxes and rates applicable to each phase of geothermal development should be clear.

STATE INCOME TAXES

Of the fifteen states which possess prominent geothermal resources, Nevada, Texas, Washington and Wyoming have no state personal or corporate income tax. Alaska, Colorado, Hawaii, Idaho, Montana and New Mexico apply their income tax levies to adjusted gross income as calculated for federal income tax.

Thus only five of the fifteen states have an independently determined income tax. These states are Arizona, California, Louisiana, Oregon and Utah.[13] Their differences from the federal law are limited, however, largely to provisions concerning percentage depletion for resource extraction industries. (Fig. 52)

Arizona

Arizona closely follows federal provisions for determining taxable income. One exception at present is a 27% depletion allowance for mineral extraction industries. According to the state Department of Revenue, income from geothermal resources production probably qualifies for the allowance.

The state, however, is very near to converting its tax policy. The Arizona Department of Revenue has requested the legislature to establish federal adjusted gross income as the base for state income tax. Reportedly, the legislature is favorable to this revision.[14]

California

Depletion. Prior to 1975, California provisions for depletion allowance in the case of oil and gas and other minerals have basically conformed to federal law. This pattern was altered by the federal Tax Reduction Act of 1975.[15]

With a few exceptions, the federal act eliminated percentage depletion for oil and gas wells. California did not adopt this policy; instead, a limit was placed on the total amount deductible by each taxpayer.

A deduction of 22% of gross income, less rentals and royalties, for the taxable year is allowed for oil and gas properties. This deduction may not exceed 50% of taxable income computed without allowance for depletion. In addition, where the deduction exceeds $1.5 million and is greater than the adjusted cost of the taxpayer's interest in the property, the deduction is reduced. The reduction equals 125% of the amount in excess of $1.5 million.[16]

For example, suppose that the 22% depletion is $3.5 million and that this amount exceeds the cost of the taxpayer's interest in the property. The deduction in this case is reduced by 125% of $2 million ($3,500,000 minus $1,500,000), which equals $2.5 million. The allowed deduction in this case is therefore $3,500,000 minus $2,500,000 which equals $1 million. If, instead, the 22% depletion amounts to $7.5 million, then the reduction is 125% of $6 million, which is equivalent to the depletion allowance itself, and no deduction is allowed.[17]

Percentage depletion is also allowed for other minerals, based on gross income from extraction and certain processing operations. In particular, extraction by mine owners or operators of ores or minerals from the waste of their prior mining is allowed depletion. A purchase of such wastes or extraction rights is not allowed the deduction.[18] This provision may be important for mineral extraction or other uses of geothermal fluids discharged from a power plant. Rates for some minerals associated with geothermal operations are as follows: sodium chloride (5%); if extracted from brine wells, calcium chloride, magnesium chloride and bromide (5%); potash (15%).[19]

Exploration expenditures. For oil and gas, California follows federal provisions which allow intangible drilling costs to be deducted from taxable income. Exploration expenditures for other minerals may be deducted under Section 17689.5 of the state tax code. Exploration expenditures for oil and gas are specifically excluded from this section, as are those for minerals not allowed percentage depletion.

Geothermal resources. California does not specifically extend special exploration, development or percentage depletion deductions to geothermal operations. In practice, however, geothermal development at The Geysers has been allowed percentage depletion and deductions for intangible drilling costs. The Geysers dry-steam res-

State	Levy	Federal Income Tax Deductible
Alaska	5.4% + 4% surtax	No
Arizona	10.5% on income over $6000	Yes
California	9%	No
Colorado	5%	No
Hawaii	5.85% first $25,000 6.435% over $25,000	No
Idaho	6.5%	No
Louisiana	4%	Yes
Montana	6.75%	No
New Mexico	5%	No
Oregon	6.5% (1976) 7% (1977) 7.5% (1978)	No
Utah	6%	Yes

Fig. 52. State tax rates on corporate net income (July 1, 1975) (from ACIR, *Significant Features of Fiscal Federalism*)

ervoir has been treated for tax purposes as a depletable gas reservoir.[20] This usage parallels federal allowances as established by the *Arthur E. Reich* and *George D. Rowan* tax cases.[21]

Water-dominated geothermal reservoirs are less likely to receive these tax benefits. If treated for tax purposes as water, geothermal resources will probably not be allowed percentage depletion or intangible drilling cost deductions.[22] At the same time, without a depletion allowance, deduction of geothermal exploration expenditures will not be allowed under Section 17689.5 of the California tax code.

Louisiana

The state basically follows federal provisions for determining taxable income. The major exception concerns the allowance for percentage depletion. Louisiana provides a 38% depletion deduction.[23]

Oregon

Natural resource extraction industries in Oregon pay a corporation excise tax on the net income of the company assignable to Oregon. Some businesses instead pay a corporation income tax; but the two taxes are figured on the same basis and at the same rate. For 1976, the rate will be 5.6%. Each year until 1978 the rate is to increase by 0.5% reaching a maximum of 7.5%.

While Oregon law does not require it, the state Department of Revenue has established federal taxable income before special or net operating loss deductions as the base for the Oregon excise tax. Certain federal deductions not allowed for Oregon net income are added back into this figure.

Percentage depletion is not allowed except on metal mines. For other natural deposits, only cost depletion is permitted. State excise tax and federal income tax are not deductible.

Many deductions allowed for federal tax purposes also apply to state net income. Federal provisions concerning, for example, intangible exploration and drilling costs, rentals, royalties and cash bonus payments apply to Oregon net income. A tax credit for pollution control facilities is also available under Oregon statutes.[24]

Utah

The state's 6% corporation franchise tax is independent of federal income tax provisions, but it is the policy of the Utah State Tax Commission to follow as closely as possible federal requirements in determination of taxable net income.

Federal tax provisions ordinarily conformed to concern depreciation, exploration expenditures, intangible drilling costs, inventories, rent and costs for research and experimentation.[25]

Depletion, on the other hand, is treated differently. Income associated with actual extraction of any natural deposits is permitted a depletion allowance. The deduction may be based either on (1) the cost of the property for which depletion is being claimed, or (2) 33.33% of net income for the property during the taxable year. Gross income is the sale price or market value of the crude material before processing. Net income for depletion is calculated by subtracting from gross income all deductions allowed by statute except for depletion. No depletion may be claimed or allowed on the net income derived from postextractive smelting, refining, fabricating or similar activities.[26]

FEDERAL INCOME TAX

Federal taxation of corporate income is the largest tax faced by geothermal operations. The levy of 48% on adjusted gross income exceeding $50,000 affects developers and investors alike. Reductions in this tax liability are achieved through allowable deductions from gross income. Among standard deductions for businesses in general are investment losses, research and experimentation costs, rent, and equipment and inventory depreciation.[27] Resource extraction industries have also been allowed resource depletion deductions, calculated as a percentage of gross income, and deductions for specified exploration and mine or well development expenditures.

The techniques and expenditures of geothermal exploration and field development are similar to those of the oil and gas industry. It is understandable, therefore, that the geothermal industry might anticipate tax deductions similar to those which have been accorded to petroleum development. In particular, percentage depletion and current deduction of intangible drilling costs have been sought. The Internal Revenue Service has not been in agreement, however, and has resisted extension of these tax benefits to geothermal development.[28]

Oil and Gas Model

Expenditures in oil and gas development have been distinguished for tax purposes according to four categories: A) expenses deducted from gross income during the period they are incurred; B) expenses capitalized, but deducted when property is abandoned; C) expenses capitalized and taken as depreciation in addition to depletion; and D) expenses capitalized and

Intangible Costs	
Stake location	$ 500
Right of way cost and surface damage	20,000
Construct road and location	50,000
Rig time 90 days @ 4000/day	414,000
Hauling	17,000
Mud and chemicals	189,054
Cement and cementing tool	50,135
Stimulation	50,000
Logging open hole	71,585
Logging cased hole	45,285
Perforating	43,915
Coring	10,000
Mud logging	84,850
Formation testing	24,530
Floating equipment centralizers	9,000
Company supervision/consultants	38,000
Bits, packers, equipment rentals	182,000
Move in, rig up, rig down	50,000
	$1,349,854

Tangible Costs	
Conductor Casing 100 ft. of 20" OD	$ 3,000
Surface Casing 2500 ft. of 13⅜" OD	48,000
Protection Casing 10,000 ft. of 9⅝" OD	216,000
Production Casing 14,000 ft. of 7⅝" OD	312,000
Tubing 11,000 ft. of 5½" OD	215,000
Wellhead	140,000
Packers, special equipment	166,400
	$1,100,400

Special Data Acquisition Equipment	
Downhole pressure recorder, chamber, surface readout and interface	21,760
Data acquisition system	73,000
Interfacing and surface system	20,000
Fluid sampling bombs and assemblies	25,000
	$ 139,760

TOTAL COSTS $2,590,014

Fig. 53. Tangible and intangible costs for a geopressured well (from Podio et al., "Plan for Geopressured Geothermal Well," p.I-66)

taken as cost depletion only when percentage depletion is not used.[29]

A) Intangible drilling costs, lease rentals and general exploration expenses have been allowed as current deductions. Intangible drilling costs include all drilling expenses except the cost of depreciable property used in drilling.

B) Lease acquisition costs for non-productive property and expenses for exploration, such as geological and geophysical studies, specific to non-productive property may be deducted when the property is abandoned. Costs of abandoned non-productive wells are also deductible.

C) The costs of tangible depreciable drilling equipment are accorded the same tax treatment as depreciable property in business generally, including rapid depreciation and investment tax credit.

D) Lease acquisition costs and exploration costs specific to productive properties may be capitalized and deducted through cost depletion, but only when percentage depletion is not used.

A depletion deduction from gross income has been allowed for oil and gas development as for other mining operations. The deduction may be calculated as cost depletion or percentage depletion, and the taxpayer is allowed to deduct the larger amount.

Percentage depletion is computed as a fraction of gross income and, as such, does not relate directly to capital costs. The allowed rates differ between minerals and have varied over time. Uranium has been allowed 22%, oil shale 15% and coal 10%. In 1969 the oil and gas allowance was reduced from 27½% to 22%, where it remained until the Tax Reduction Act of 1975.[30] In every case, though, a calculated minimum tax must be paid, and the depletion deduction may not exceed 50% of net income from the property.

Cost depletion is computed according to (a) the purchase price or the capitalized costs of the property (the basis), and (b) the estimated recoverable reserves remaining in the property when the deduction is taken. Lease acquisition and exploration expenses specific to the property contribute to the basis. The portion of the basis deductible for a tax year is equivalent to the portion of remaining recoverable reserves produced during that year. Percentage depletion is taken when it is larger than the computed cost depletion allowance; in this case, the basis is reduced by the amount deducted.

TAX BENEFITS

The benefits of special development deductions and percentage depletion for mining and petroleum development under the federal 48% income tax have been analyzed by Gerard Brannon of Georgetown University. These benefits accrue over and above those available through depreciation and other standard business deductions. His results are sketched below and extended to state income tax rates. Their potential value in geothermal development is then examined.

Current Deduction

Dr. Brannon calculated the stream of tax benefits on a dollar of drilling cost when depreciated over a 20-year well-life using the sum-of-the-years'- digits method.[31] With a 9% discount factor, the present value of those deductions against a 48% tax is $0.257. The value of a current deduction for the dollar investment, effective one year later, is $0.44 (i.e., $.48/1.09).

The same calculation can be made for a state tax rate of 5% to 10%. The result for the 48% tax is simply scaled according to the alternate tax rate. With a 5% tax, depreciation is worth $0.0268 (i.e., $0.257 x .05/.48); current deduction is worth $0.0459 (i.e., $.05/1.09).

The difference between the present values of current deduction and depreciation of the investment is the special benefit of current deduction. It is equivalent to an investment credit. Under federal income tax, the benefit of current deduction is equivalent to an 18% investment credit; with a 5% to 10% state income tax, the benefits are equivalent to a 1.9% to 3.8% investment credit. (Fig. 54) The benefits of current deduction are accorded to expenditures in non-productive properties and, for petroleum, to intangible drilling costs.

Tax Rate	Value of Current Deduction	Value of Amortization	Difference (Equivalent Investment Credit)
48%	.440	.257	.18
10%	.0459	.0268	.019
5%	.0918	.0536	.038

Fig. 54. Benefits from current deduction of $1 investment compared to 20-year amortization (from Brannon, "Existing Tax Differentials," p.8)

The deduction for non-productive properties is not a benefit totally in excess of standard business deductions. Loss deductions are available to business generally. But treatment of expenditures in non-productive resource properties as losses, rather than as investments, provides a special benefit. An oil and gas asset has usually been discovered only after numerous investments in non-productive exploration. Where, in business generally, expenditures to secure an asset must be capitalized, in oil and gas development all expenditures may be deducted, except for the final (relatively small) productive investment. Because of this special benefit, Brannon considers three-fourths of the deduction (13.5%) unneutral with respect to normal business enterprises.[32]

Figure 55 shows the deductions taken in 1959 for oil and gas development expenditures. The overall benefits are calculated as equivalent to a 13% investment credit. It may also be noted that the deduction of intangible drilling costs accounted for 47% of these benefits.

Character of expense	Amount $ million	Special tax benefit
Exploration other than drilling		
productive wells	236	No credit, equivalent of normal cost depreciation*
non-productive wells	955	13.5 investment credit
Drilling costs		
tangible	549	Normal 7 percent investment credit plus normal depreciation.
intangible	1,281	18.0 investment credit
non-productive wells	821	13.5 investment credit
Total investment expense	3,842	
Tax credit equivalent	495	(.135) 955 + (.07) 549 + (.18) 1,281 + (.135) 821
Overall implicit credit rate		13 percent

*This can be regarded as available as normal depreciation since we treat the excess in percentage depletion as the amount in excess of cost depletion.

Fig. 55. Expenditures for oil and gas wells (1959) classified by tax treatment (Reprinted with permission of Ballinger Publishing Company from *Studies in Energy Tax Policy*, Copyright 1974, The Ford Foundation)

Tax Benefit	Oil & Gas	Coal	Uranium
(1) Gross rate	22%	10%	22%
(2) Rate adjusted for the minimum tax rate	20	10	22
(3) Rate adjusted for the net income limitation	19	5	14
(4) Rate adjusted for cost depletion that would have been allowed	15	4	8
(5) Adjusted for drilling/development expenses, expressed as a depletion	6	0.4	1.3
(6) Total tax benefit	21	4.4	9.3

(1) These are the statutory rates for percentage depletion applied to gross income.

(2) There will probably be some small overall burden of minimum tax on companies in coal and uranium but we have no data.

(3) Determined from comparing depletion at statutory rate with percentage depletion allowed SOI Depletion 1960 p.37.

(4) The coal adjustment was set equal to the proportionate adjustment for oil and gas since the actual cost depletion taken was 10% of percentage depletion in both industries; cost was 20% of percentage in uranium.

(5) From the investment credit-equivalent analysis we concluded that intangible deductions for oil and gas were 39% of the percentage depletion benefit, pp. 10-11. The corresponding price equivalent ratios are 15 percent and 6 percent. In oil and gas, the development deductions, including deductions on non-producing property, in total were about 110% of the percentage depletion deduction. In coal the corresponding share was 25% and in uranium 55% SOI Depletion 1960 p. 37).

Fig. 56. Net benefit of percentage depletion and deduction of drilling/development expenses as a percentage of mine or well-mouth price, oil and gas, coal and uranium (Reprinted with permission of Ballinger Publishing Company from *Studies in Energy Tax Policy*, Copyright 1974, The Ford Foundation)

Percentage Depletion

Figure 56 compares the benefits of percentage depletion deductions for petroleum, coal and uranium when the minimum tax and net income limitations are included. At line five, the tax benefits associated with development expenses are converted to equivalent depletion allowances.[33]

Tax Benefits for Geothermal Development

Current deduction. Current deduction of intangible drilling costs, if allowed for geothermal wells, would have the same importance as it does for oil and gas development. In fact, the relatively higher costs of drilling geothermal compared to oil and gas wells would increase the weight of this deduction. Where intangibles constitute 50% of drilling expenses, as in Figure 53, their current federal deduction would be worth $45,000 for each $500,000 in well costs. Under a 5% to 10% tax, the deduction is worth $4,750 to $9,500.

Assuming an income of 10-20 mills/kwh of power generation and an 80% plant load factor, annual gross income per megawatt to the supplier is equal to:

1000 kw × 7000 hrs/yr × ($.01/kwh to $.02/kwh) = $70,000-$14,000/MW/yr.

With a 48% tax, the annual value of a 15% depletion deduction equals:

($70,000-$140,000) × 15% × 48% = $5040-$10,080/MW/yr.

The present value of this stream of tax benefits over 20 years, with a 9% discount factor, is equal to:

($5040-$10,080) × 9.1 = $45,860-$91,720/MW.

The same calculation performed for tax rates of 5%-10% shows the depletion deduction to be worth $4780/MW to $9560/MW when supply price is 10 mills/kwh; $9560/MW to $19,120/MW when it is 20 mills/kwh.

Fig. 57. After-tax value of percentage depletion for geothermal resources

Percentage depletion. As indicated in Figure 56, the value of percentage depletion depends on more than the statutory rate. A 22% allowance for the petroleum and uranium mining industries yields disparate benefits, due largely to the unequal effects of the net income limitation. For geothermal development, the net income limitation would be least restrictive in the case of readily accessible dry-steam fields. Water-dominated reservoirs, particularly those with fluids high in dissolved solids and non-condensible gases, economically are more marginal at power costs competitive with established fuels. Development of these fields would therefore benefit less from a percentage depletion allowance which includes a net income limitation.

At the Geysers, steam is supplied for approximately 10 mills/kwh. The calculations of Bloomster and Knutsen (Fig. 43) indicate that geothermal energy supplied from water-dominated reservoirs may more typically cost 20 mills/kwh, with generation costs still competitive with other power sources.

In Figure 57, tax benefits of percentage depletion at the effective rate for petroleum (15%) are calculated assuming supply prices of 10 mills/kwh and 20 mills/kwh.[34] With a 48% tax rate, the present value of percentage depletion to the supplier is $45,860/MW to $91,720/MW according to the supply price. Under 5% to 10% tax rate the value is $4,780/MW to $9,560/MW (10 mills/kwh); or $9,560/MW to $19,120/MW (20 mills/kwh).

This estimate indicates that the after-tax value of an effective 15% depletion deduction is approximately 5-10 times greater than current deduction of intangible drilling costs, assuming the average $500,000 geothermal well produces 5 MW of power for 20 years.[35]

Tax benefits to the developer are compared in Figure 58 with royalty income to federal or state treasuries. A 10% royalty on gross income from the well yields $7,000-$14,000 per year, and the discounted present value of this income over 20 years equals $318,500 (10 mills/kwh) to $637,000 (20 mills/kwh). Tax benefits to the developer from percentage depletion and current deduction of intangible drilling costs are $274,300 (10 mills/kwh) to $503,600 (20 mills/kwh) under federal tax; $28,650 to $105,100 under state tax, depending on the rate and supply price.

Tax Benefits and Investment

The value of a percentage depletion allowance and current deduction of intangible drilling costs exceeds their influence on a developer's after-tax income. These tax benefits would also greatly enhance the ability of geothermal development to attract investment capital.

Percentage depletion and deduction of intangible drilling costs reduce the risks of investment. A taxpayer in the 40% tax bracket who invests $10,000 for intangible drilling costs would effectively be risking $6,000.[36] With a 22% depletion allowance, the return on investment is increased by 22% of the gross income multiplied by the effective tax rate (federal or state income tax rate x 22% x gross income from the property).[37]

For geothermal resources to contribute significantly to the nation's energy supply, thousands of wells must be drilled. To produce 10,000 MW of electric power by 1985, 2000 commercial wells of 5 MW would be required in the next eight years. Assuming an average cost of $500,000 per well and 80% success in drilling, the cost would be $1.2 billion. These calculations assume that no new discoveries must be made. To bring on line the 100,000 MW capacity reasonably expected to exist just in hydrothermal convection reservoirs, as seen earlier, thousands of exploratory wells will be needed to prove the reservoirs, in addition to 20,000 to 40,000 commercial production wells and a comparable number of disposal wells. If capital is made available, these are not impossible goals; after all, over 35,000 oil and gas wells are drilled each year.

To finance significant development of geothermal resources, however, the industry must go to the capital markets. An investor faced with a decision between two drilling prospects, one for geothermal resources and one for oil and gas, will not need to hesitate if tax benefits are only associated with petroleum investments. Geothermal development is the unknown, and without tax benefits to ameliorate investment risk at least comparable to the other energy sectors, the geothermal industry is not likely to command its share of investment capital.

Tax Rate	Intangible Drilling Cost Deduction	15% Effective Depletion Allowance		Total Tax Benefits		10% Royalty Income to Lessor	
		10 mills/kwh	*20 mills/kwh*	*10 mills/kwh*	*20 mills/kwh*	*10 mills/kwh*	*20 mills/kwh*
State, 5%	$ 4,750	$ 23,900	$ 47,800	$ 28,650	$ 52,550	$318,500	$637,000
State, 10%	9,500	47,800	95,600	57,300	105,100	318,500	637,000
Federal, 48%	45,000	229,300	458,600	274,300	503,600	318,500	637,000

Fig. 58. Tax benefits for a 5 MW, $500,000 geothermal well

Notes

1) Colorado Legislative Council, *Mineral Taxation*, pp.5-47.

2) Robert H. Paschall, Senior Petroleum and Mining Appraisal Engineer, California State Board of Equalization: Oral Communication;
William Lawver, Lake County Assessor: Oral Communication.

3) Carel Otte, "Remarks at the California Conference on the Business Climate," pp.7-9.

4) See, for example, the testimonies of Dr. J. Herbert Snyder and Dr. Curtis C. Harris, Jr., before the Assembly Interior Committees on Revenue and Taxation and Agriculture, California State Legislature, Fresno, California, January 30, 1964.

5) Gary Vise, Chief Appraiser, Sonoma County, Santa Rosa, California: Oral Communication.

6) Assessment based on well-head production is the method employed for oil and gas in Arizona, Colorado, New Mexico and Wyoming.

7) Robert H. Paschall, "Taxation of Mines in Nevada";
see also Bulletin 135, Nevada Tax Commission, July 1, 1975, pp.11-12. This bulletin establishes the guidelines for assessing geothermal leases.

8) Seth Franzman, Administrator, Utilities and Mines Section, Division of Property and Special Taxes, Arizona Department of Revenue: Oral Communication.

9) Commerce Clearing House, *State Tax Handbook*, October 1, 1975;
for Hawaii, see Robert M. Kamins and Donald Kornreich, *Legal and Public Policy Setting for Geothermal Resource Development in Hawaii*, pp.57-62.

10) Chapter 289 (S.B.186), New Mexico Laws of 1975. The conservation tax is set at 0.18% of taxable value. The taxable value of geothermal energy is the "value at the point of first sale, less the cost of transporting it from the point of severance to the point of first sale, less the royalties paid or due the United States or the state of New Mexico or any Indian tribe, Indian pueblo or Indian that is a ward of the United States of America." (Section 72-20-5(D) NMSA 1953 as amended)

11) Colorado Legislative Council, *Mineral Taxation*, Table VIII, pp.44-45.

12) Harold DeBolt, Director, Ad Valorem Tax Division, Wyoming Department of Revenue and Taxation: Oral Communication.

13) Advisory Commission on Intergovernmental Relations, *Significant Features of Fiscal Federalism*, p.290.

14) Arizona Department of Revenue: Oral Communication.

15) Russell S. Bock, *Guidebook to California Taxes: 1975*, pp. 141-142.

16) CALIFORNIA REVENUE AND TAXATION CODE, Section 17686.

17) Bock, *Guidebook to California Taxes*, p.142.

18) CALIFORNIA REVENUE AND TAXATION CODE, Section 17688.

19) Ibid., Section 17687.

20) William Helman, Coopers and Lybrand: Oral Communication.

21) Arthur E. Reich, 52 T.C. 700 (1969), *aff'd.* 454 F.2d 1157 (9th Cir. 1972);
George D. Rowan, 28 T.C.M. 797 (1969);
see, Samuel M. Eisenstat, "Tax Treatment of Exploring and Developing Geothermal Resources";
Donald B. Elmer and Kathryn E. Rogers, "Legal Issues in the Development of Geothermal Resources of Texas and Louisiana Gulf Coast," pp.133-146.

22) William Helman: Oral Communication.

23) Virgil Brady, Corporation Income And Franchise Tax, Louisiana Department of Revenue: Oral Communication.

24) Information on Oregon excise tax courtesy of Don Hillman, Corporate Auditor, Oregon Department of Revenue: Oral Communication.

25) Utah State Tax Commission, "Utah Corporation Franchise Tax Regulation No.14 (A12-02-F14): Extent to which Federal Income Tax Provisions are Followed for Corporation Franchise Tax Purposes."

26) Utah State Tax Commission, "Utah Corporation Franchise Tax Regulation No.12 (A12-02-F12): Depletion."

27) Utah State Tax Commission, "Tax Regulation No.14."

28) Samuel M. Eisenstat, "Reducing the Risks in Geothermal Exploration: A Tax Update," pp.93-94.

29) This discussion of petroleum taxation tracks Gerard M. Brannon, "Existing Tax Differentials and Subsidies Relating to the Energy Industries";
see also Public Land Law Review Commission, *Legal Study of Geothermal Resources on Public Lands*, pp.132-147.

30) Bock, *Guidebook to California Taxes*, p.141.

31) Brannon, "Existing Tax Differentials," p.8.

32) Ibid., pp.9-10; see also Gerard M. Brannon, "U.S. Taxes on Energy Resources."

33) Brannon, "Existing Tax Differentials," p.17.

34) In fact, the effective rate for geothermal resources may be quite different than that for petroleum in 1970. And as noted, the effective rate for various geothermal reservoirs also must vary.

35) Wells at The Geysers produce 8-10 MW of power (rather than 5 MW), but have lifetimes closer to 10 years. The tax benefits of both current deduction of intangibles and percentage depletion are therefore greater, although their relative weights are approximately the same (compared to well conditions assumed in the calculation in Figure 57).

36) The federal tax rate for personal income is not limited to 20%, 22% and 48%, as is corporate income. A married couple filing a joint return with taxable income between $24,000 and $28,000 would owe $5,660 plus 36% for income over $24,000. If their taxable income were $44,000-$52,000, they would owe $14,000 plus 50% of income above $44,000. Personal income exceeding $200,000 is taxed at 70%.

37) Samuel M. Eisenstat, "Geothermal Exploration and Development in the United States: A Tax Analysis under the Internal Revenue Code."

5

State Geothermal Leasing and Development Regulations

INTRODUCTION

As regulators and proprietors of public lands and resources, states directly influence industry's access to geothermal reservoirs. Private appropriation is affected by state treatment of the resource, whether as water, mineral, gas or *sui generis;* state lease provisions determine the security of a leasehold and influence its profitability; and state regulations constrain the industry's methods of development.

The most prominent geothermal resources occur in the thirteen western states, in Texas and in Louisiana. In each state, authority and guidelines are established for administration of geothermal leasing and development. The states have characterized the resource; they have identified available lands and the methods for leasing; and they have provided for statewide regulation of development.

The major features of state leasing regulations are concerned with 1) characterization of the resource, 2) access for exploration, 3) the manner of granting geothermal leases, 4) rental and production royalties, 5) lease terms and adjustments, and 6) regulation of geothermal operations.

State development regulations control methods of drilling, resource production and waste disposal. They monitor and restrict environmental degradation and help ensure that geothermal resources are not wasted.

Most states enacted extensive new law to accomplish these tasks, although three states (Utah, Nevada and Wyoming) have relied mostly on existing statutes. (See Appendix 1) California and New Mexico led in the 1960s, and the other states have followed in the '70s, benefiting from their state forerunners and from the federal Geothermal Steam Act of 1970.

STATE LEASING: RESOURCE DEFINITION

Definitions of geothermal resources have two basic tasks. The first is to describe the physical properties which distinguish geothermal resources from other natural resources. This enumeration of parts identifies the creature that is thereafter subject to geothermal leasing, taxes and development regulations.[1] In some manner, a definition also needs to relate geothermal resources to groundwater, subsurface minerals and other established resources.[2] A resource definition is therefore both anticipative and retrospective. It looks forward to future leases and development, and looking backward, it seeks to place geothermal resources into the structure of leases, reservations and property titles inherited from the past.

In formulating their geothermal statutes, most states have referred extensively to prior law, in particular to the California Geothermal Resources Act of 1967 and to the federal Geothermal Steam Act of 1970. As will be seen, however, their definitions and regulatory classifications for geothermal resources differ in important respects. This divergence results in part from the complexity of the resource. In part, too, it derives from the unique histories of the states; the presence or absence of extensive petroleum development, for example, or special concerns in water regulation have been reflected in state laws concerning geothermal resources.[3]

Resource Categories

In part, geothermal resources are akin to water, to gases and to minerals. This complexity makes difficult the task of relating geothermal to other established resource categories. Existing water rights, mineral titles, surface and subsurface estates form an intricate tangle, and attachment of geothermal rights to one of them will certainly disturb the rest.

Most states and the federal government have refrained from making such an assignment. The exceptions are Hawaii (mineral); Idaho, Montana and Washington (*sui generis*); and Wyoming (underground water).[4] Hawaii lays claim to geothermal resources wherever the state controls the minerals. As an underground water, geothermal resources in Wyoming are designated a public resource subject to appropriation under state laws. And according to their declaration (*sui generis:* "being neither a mineral resource nor a water resource") , Idaho, Montana and Washington have retained the rights to geothermal resources in all sales and leases other than established geothermal leases.[5]

The *sui generis* classification excludes geothermal resources from usual resource categories. Other states similarly have approached the classification problem through exclusion. Colorado has declared that geothermal resources are not mineral. The statute reads, "Reference to minerals in any conveyance shall be presumed not to include geothermal resources unless specific reference is made to such resources in the conveyance."[6]

Most states specifically distinguish geothermal resources from hydrocarbons and, in some instances, helium. More subtle distinctions, particularly in relation to water, are made when states describe the physical character of geothermal resources.

Physical Portrait

Either in their statutes or administrative codes, each of the states has given a sketch by which to identify geothermal resources. Two accounts of the resource, which appear as "definitions" in the California Geothermal Resources Act of 1967 and in the federal Geothermal Steam Act of 1970, have served as models for most other states.[7]

Definition 1: California Geothermal Resources Act

> "Geothermal resources" shall mean the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances.

Definition 2: Federal Geothermal Steam Act

> "Geothermal steam and associated geothermal resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them.
>
> "Byproduct" means any minerals (exclusive of oil, hydrocarbon gas, and helium) which are found in solution or in association with geothermal steam and which have a value of less than 75 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves.

Only Nevada and Washington have not made use of these definitions. (Fig. 59) An August 1965 opinion of the Deputy Attorney General of **Nevada** classed geothermal resources as water, and they have been regulated accordingly.[8] Recent legislation re-defined geothermal resources, however, as "heat or other associated geothermal energy found beneath the surface of the earth." This legislation authorized the State Engineer to adopt special regulations governing geothermal development in the state.[9]

In 1974, the state of **Washington** characterized geothermal resources explicitly in terms of their use. The definition restricts the act's leasing and regulatory provisions to:

> only that natural heat energy of the earth from which it is technologically practical to produce electricity commercially and the medium by which such heat energy is extracted from the earth, including liquids or gases, as well as any minerals contained in any natural or injected fluids, brines and associated gases, but excluding oil, hydrocarbon gas and other hydrocarbon substances.

Any other use of naturally heated fluids—whether "byproduct water resources" from geothermal electric generation, or the production of wells not suitable for electric generation—must be authorized through the state's water appropriation procedures.[10] Such fluids, by virtue of their use, are water resources rather than geothermal resources.

California Model	Federal Model	Other
Alaska*	Alaska*	
	Arizona	
	Colorado	
Hawaii		
Idaho		
	Louisiana	
Montana		
		Nevada
Oregon*	Oregon*	
	Texas	
Utah (Draft Regulations)		Utah (no statutory definition)
		Washington
Wyoming (Lease Form)		Wyoming**

*Alaska and Oregon have combined the federal and California models. The result is effectively the federal definition.

**Wyoming has declared "geothermal steam and hot water" to be underground waters, but geothermal resources are not further characterized in the statutes.

Fig. 59. Types of definitions adopted by the states for geothermal resources

To be comprehensive, a definition of geothermal resources should classify all recognized types of geothermal occurrences. Ideally, it would also be broad enough to allow for new forms which may be discovered. In this regard, the four definitions listed above could very well be more specific. Magma, hot dry rock, geopressured and regional heat flow reservoirs are not clearly included or excluded as geothermal resources. Hydrothermal reservoirs seem to have been most in the minds of their authors. As a consequence, some important elements of the resource may fall outside these definitions. Pressure is one example.[11]

Modifications of the Federal Definition

In adopting the federal definition of geothermal resources, Louisiana, Texas, Arizona and Oregon have made modifications with specific conditions in mind. To bring the elements of geopressured reservoirs (heat, fluid pressure, dissolved natural gas) within its definition, **Louisiana** stipulated that geothermal resources include "heat, dissolved natural gas or other associated energy found in geothermal formations." Oil and natural gas continue to be excluded as *byproducts* of geothermal resources.[12]

With the same purpose, **Texas** provided that geothermal energy and associated resources include "all products of geothermal processes, embracing indigenous steam, hot water and hot brines, and geopressured waters." The language of the federal definition is maintained thereafter, until "byproduct" is defined. The Texas statute reads: "The term 'byproduct' means any element found in a geothermal formation which when brought to the surface is not used in geothermal heat or pressure inducing energy generation."[13]

Through these modifications, Louisiana and Texas have clearly brought elements of geopressured reservoirs within their resource definitions. Louisiana specifies natural gas dissolved in geothermal formations as a geothermal resource; pressure and oil may be included as "other associated energy." Texas clearly identifies geopressured waters as geothermal resources, including it would seem, natural gas, oil and other dissolved constituents as byproducts.[14] One practical difference between the Louisiana and Texas definitions concerns royalties. Generally the primary geothermal resource and byproducts are subject to different royalty charges. Thus natural gas in Louisiana and Texas geopressured reservoirs probably will yield quite different royalty payments under these statutes, although at this time none have been set.

Arizona also adopted a somewhat altered form of the federal geothermal definition. The "byproduct" section is replaced by the simple inclusion as geothermal resources of any "mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water or brines." The drafters of the Arizona statute also had in mind schemes which have been advanced to augment heat production in geothermal reservoirs by nuclear or other types of explosions. Energy of this sort falls under the third clause of the Arizona definition: "Geothermal resources means—(3) Heat or other associated energy found in geothermal formations, including any artificial stimulation or induction thereof."[15]

The Arizona, Louisiana and Texas modifications to the federal definition constitute a critique of the original language. It may be argued that the changes were unnecessary since the federal clause "all products of geothermal processes" and the inclusion of "associated energy found in geothermal formations" take account of known geothermal and geopressured reservoirs; and perhaps even energy artificially introduced into the formation.

If used in this way, however, the definition would become entirely too broad. Its main function, which is to distinguish geothermal resources from other natural occurrences, would be frustrated. Most mineral formations are products of geothermal processes. Coal and diamonds are two well-known instances. Too many things are snared by such all encompassing phrases.

The term "hot water" in the federal definition may also be criticized as imprecise. All water, all substances, in fact, contain heat—its presence is not sufficient to identify a geothermal resource. Some restrictions are needed, in terms either of temperature or applications of the heat.

Only **Oregon,** of the states which make use of the federal definition, provides such additional restrictions. The Oregon statute distinguishes between hot waters according to temperature and well depth. Hot water from wells deeper than 2,000 feet must be developed according to geothermal statutes. Hot water from shallower wells with bottom-hole temperatures less than 250°F must be developed according to state water law. It is not necessary, however, to know the bottom-hole temperature of wells before they are drilled. All geothermal prospecting is regulated under the geothermal statutes.[16]

The California Definition

Pressure and artificially generated heat are not specifically included within geothermal resources as defined by the California statute. Otherwise, the definition is fairly successful in characterizing geothermal resources and distinguishing them from other natural resources. Subsurface heat as a form of energy is identified as the main resource component, which requires a transfer medium—water, steam or brine—for production. Substances or products of thermal processes are not included in the resource, except for minerals or gases entrained in the produced fluid.

The produced fluid is itself excluded from the resource.[17] This important feature differentiates the California and federal definitions. The geothermal developer under the California statute obtains title to produced fluids by means of a separate legal instrument—a certificate of primary purpose.[18] The conditions of the certificate are set out in the Public Resources Code as follows:

> Any person having drilled a well or wells on state, federal or private lands which are producing geothermal resources, may, at any time, apply to the board for a certificate of primary purpose. When the board determines that such well or wells are primarily for the purpose of producing geothermal resources and not for the purpose of producing water usable for domestic and irrigation purposes, the board shall issue a certificate of primary purpose to such person. Such certificate shall establish a rebuttable presumption that such person has absolute title to the geothermal resources reduced to his possession from such well or wells. Such presumption may be rebutted only upon a showing that the water content of the geothermal resources is useful for domestic or irrigation purposes without further treatment thereof, but not by virtue of any production of such water as a by-product incident to the production of the geothermal resources.

The certificate of primary purpose is a key adjunct of the California definition; together they distinguish water resources from geothermal resources by restricting the uses to which geothermal resources are applied. If produced fluids may be applied without special treatment to recognized domestic and irrigation water uses, then rights to them are not attached to geothermal resources or to geothermal development rights. Space heating, fish farming and irrigation are uses of hot water likely to fall under the state's water statutes, unless the fluid is quite saline.

Five other states (Hawaii, Idaho, Montana, New Mexico, Utah) rely on a version of the California definition to characterize geothermal resources.* Only California, however, provides the geothermal developer a method to appropriate geothermal fluids outside of established water appropriation procedures. In Hawaii, as it otherwise would in California, this means securing water rights from the surface holder. In the other four states, underground water is a public resource and appropriation rights are obtained from the state.

*Alaska and Oregon combine the California and federal definitions, which effectively results in the federal definition. Wyoming uses the California definition in its lease forms, but defines geothermal steam and hot water by statute as underground waters.

The water appropriation requirement is the most important difference between California's geothermal law and its derivatives in other states. Water in the West is a scarce and, in some instances, overappropriated commodity. New water rights may be impossible to obtain and the cost of purchasing established rights prohibitive at the requisite volumes.

It is possible that water permit requirements will be troublesome mostly as an administrative delay, given that appropriation rights are necessary only for *net* water consumption. If, however, simple production of fluid requires water rights for the entire volume, as currently in Utah and Nevada, geothermal development could suffer severely from a legal water shortage.

Conclusions

The established definitions of geothermal resources are not as effective as might be wished. They do not clearly identify types of physical occurrences held to be geothermal resources, and they do not adequately segregate geothermal from other natural resources, in particular water.

The first weakness could be eliminated by specific reference in the definitions to magma, hot dry rock, regional heat flow, geopressured and hydrothermal convection systems as known types of geothermal resources, with their physical details accurately described.[19]

The definitions also need to more thoroughly separate established water resources from geothermal resources. As noted above, groundwater in the West is a precious substance. In many areas it is fully appropriated, and a general water appropriation requirement to produce geothermal fluid, as though it were irrigation water, may seriously constrain geothermal development. Very large fluid withdrawal is required: typically, 100,000 acre-feet per year of hot water to supply a 200 MW powerplant.[20] At the same time, usually less than 20% of this fluid will be consumed, mostly in evaporation cooling.[21]

In distinguishing geothermal and water resources, interference is the primary concern. Does geothermal production interfere with established water resources? In many instances, as when brines are produced from 12,000 feet, a strong case may be made that the geothermal fluid has no substantial connection with established water resources. On the other hand, potable, 85°F fluids from shallow wells may justifiably be held as water resources, even though they are desired only for their heat content. The difficulty in distinguishing geothermal and water resources results from this range of fluids valuable for their heat.

An adequate definition of geothermal resources will recognize that geothermal fluids grade into standard groundwater, but that a rule is needed to separate them where no interference exists. Water rights must be protected. At the same time, conjectured interference should not obstruct geothermal development.

Separation of geothermal fluids and established water resources may be accomplished in a number of ways. First, fluids in geothermal formations may be defined as a resource constituent. This provision would follow the present federal definition. The excessive breadth of the federal provision would be eliminated, however, by specifying a minimum formation temperature (e.g., 80°C). The actual temperature selected should be such as to include most geothermal applications, in particular electric generation, but to exclude most established water resources. The temperature limit follows the Oregon approach without the complicating depth provisions. It also accounts for the use limitations found in the California and Washington definitions.

The statute, in addition, should specify that production of geothermal fluids is presumed not to interfere with established water resources unless substantial adverse effect can be demonstrated by positive evidence. This provision would protect established water rights and simultaneously remove unnecessary obstacles to geothermal development.[22]

If a general water appropriation requirement is maintained for geothermal fluids, it may be made nearly equivalent to the approach just outlined. This would be accomplished by a statutory rebuttable presumption, as above, that production of geothermal water does not interfere with established water rights. That is, geothermal fluids would be deemed developed water unless substantial adverse effect on established water rights could be demonstrated.[23]

To manage instances where geothermal fluids grade into groundwater, the states should provide by statute that if a water appropriation right is necessary, it will be required only for consumptive use. This provision is appropriate to the character of geothermal development. As noted, electric generation generally will consume less than 20% of the produced fluid. If groundwater at 85°F is used with heat pumps for heating and cooling buildings, virtually all of the water is available for subsequent use. The consumptive use provision would help remove purely artificial water constraints on geothermal development.

STATE LEASING: RESOURCE ACCESS

Numerous means are available for the transfer of public resource rights to private developers. Resources may simply be conveyed without charge; federal mining claims and non-competitive oil and gas leases distribute resource rights in this way. Resource rights may also be distributed through bidding procedures. Factors which may be bid include cash bonuses, annual rentals, production royalties, profit shares, and work commitments. In both "free" transfers and competitive bidding, developers may in addition incur specified work commitments, annual rentals and production royalties.[24]

A two-tiered access procedure may also be employed which allows non-competitive access for some lands, but requires competitive bidding for particularly valuable resource areas. Forms of this approach have been adopted by most states and by the federal government for leasing of geothermal resources. The principal intent is to grant non-competitive access for areas of low or unknown potential, but to require competitive bidding for known geothermal resource areas (KGRA). Montana and Washington are exceptions among the states as they require competitive bidding for access to any state lands for geothermal exploration or development.

State	Manner Awarded	Term	Conversion Privilege	Annual Rental
Alaska	By application	3 years, possible 2-year extension	yes	variable: $1/acre minimum
California	By application	3 years, possible 2-year extension	yes; 90-day period	$1/acre
Hawaii*	By application	2 years, possible 1-year extension		variable (to occupier)
Wyoming	a) Public drawing** b) By application	3 years, possible 2-year extension	yes; 90-day period	$1/acre

*Draft regulations

**When lands are newly offered for exploration, a period is set of at least thirty days and applications received during that period are awarded permits by public drawing.

Fig. 60. State geothermal exploration permits

Two types of non-competitive access are granted for geothermal resources. Some states issue short-term exploration permits. (Fig. 60) In this case, the permittee also is granted the right to convert areas under permit to development leases if they are reclassified as KGRA (for example, through a discovery by the permittee). Other states simply issue non-competitive, long-term leases. (Fig. 61)

When lands not leased or under permit are determined to have significant geothermal value (KGRA—the second tier of the system), developers must obtain leases through competitive bidding, the terms of which vary among the states.

With two-tiered access, the states have sought to encourage exploration of unknown lands while retaining the income benefits from ownership in known geothermal areas. This approach permits the entry of small operations into the geothermal industry and provides an incentive generally for exploration. On the other hand, non-competitive leases, and exploration permits with preferential conversion rights, give developers control of geothermal resources upon state lands for very little cost. And when a discovery is made, the value of ownership accrues totally to the developers and nearby property holders. Accumulation of geothermal properties is encouraged in this way.

To reduce revenue losses and to discourage accumulation of land for speculation, the states have relied on fixed royalties, acreage limitations and lease adjustments. (Fig. 62) Some states have also modified bidding procedures.

Acreage Limitations

Restrictions on the size of the individual leases and on total lease holdings permitted for any one party are necessary to orderly resource development. Minimum area limitations prevent excessive fragmentation, and maximums inhibit monopolization of the resource.[25] To be effective, however, acreage bounds must recognize the exigencies of resource development.

The states generally have set quite small lease sizes for geothermal resources. Four states limit individual leases to a maximum of 640 acres; another four use this as a minimum and set 2,560 acres as the maximum lease size. The larger of these two figures is itself small. Small lease size diminishes the value of geothermal development by reducing expected income from reservoirs and by increasing time and financing needed to procure access.

As noted earlier, at least 2,000 acres are required for a 200 MW hot-water field. This generally will be the minimum size feasible for development.[26] With large errors involved in locating the center and actual dimensions of a geothermal reservoir, in most cases fields will span a number of 2,560-acre leases. Division of a reservoir between separate leaseholds reduces the average value of geothermal discoveries. In addition, where resource areas are divided, exploration is delayed, as each leaseholder seeks to benefit from exploratory work performed by the remaining participants in the area.[27]

Before discovering a 200 MW reservoir, 150,000 to 500,000 acres on the average will first have been examined and approximately 80,000 to 240,000 acres leased. Even if each one is the maximum 2,560 acres, 30 to 90 leases will be required. Difficulties in obtaining leases in a timely manner and in the desired locations become quite significant where such considerable numbers are involved.[28]

Alaska, California and Idaho impose limits on total lease holdings in addition to lease size restrictions. Alaska and California forbid holdings in excess of 25,600 acres (the federal limit is 20,480 acres/state). Idaho disallows interest in more that 50 township-and-ranges. Thirty-six sections of 640 acres, or 23,040 acres, constitute a township-and-range. The Idaho limit therefore prevents checkerboard speculation, rather than large acreage holdings.

Risk in geothermal exploration, as in other pursuits, is managed by distributing investment between a number of chances. The total acreage limitations now in force restrict this method of risk distribution to at most two or three opportunities of 7,500 to 10,000 acres. If a developer has been successful and holds productive acreage, his ability to explore new prospects is correspondingly reduced.

This analysis suggests that maximum lease sizes should be larger. Limitations on total holdings should also be expanded and productive acreage exempted.[29]

State	Non-KGRA Lands		KGRA Lands (Competitive Leasing)	
	Newly Offered	*Application Overlap*	*Bidding Factor*	*Designation Criteria*
Alaska	....	....	(A)	(A)
Arizona	By Application	Qualifications or Cash Bonus Bidding	Cash Bonus	Geology and/or competitive interest
California	....	....	Cash Bonus or other	Producing Well
Colorado	(A)	(A)	(A)	(A)
Hawaii	.....(B)	.....(B)	Annual Rental (B)	Producing Well (B)
Idaho	Public Drawing (30-day filing)	By Application		Producing Well
Louisiana	(B)	(B)	(B)	(B)
Montana	Competitive	Competitive	Cash Bonus	All lands awarded competitively
Nevada	(C)	(C)	(C)	(C)
New Mexico	Competitive (3-day filing)	By Application	Cash Bonus	Determined by Commissioner of Lands
Oregon	Public Drawing (30-day filing)	By Application	Cash Bonus (D)	Geology and/or producing well
Texas	(B)	(B)	(B)	(B)
Utah	Cash Bonus (E) (15-day filing)	By Application	(E)	(E)
Washington	Competitive	Competitive	Cash Bonus (F)	All lands awarded competitively
Wyoming	....	....	(A)	(A)

(A) Specified by state land commissioners
(B) Regulations not finalized
(C) Moratorium on leasing of state lands
(D) If no bids received, Division of State Lands may reclassify for non-competitive leasing.
(E) Lands are offered non-competitively by order of application, except when they are newly offered. Newly offered lands are leased by cash bonus bidding.
(F) Unlike Montana, if a tract receives no bid, it is withdrawn.

Fig. 61. Leasing of state lands

Rentals and Royalties

State leases generally provide for production royalties (10-15%) and minimal rentals $1-$2/acre). Annual rentals are a small charge for the opportunity to undertake intensive use of public lands. They serve largely to defray regulatory costs. Royalties on production, along with cash bonuses for competitive leases, act to hold some portion of the public resource value in the public treasury.

Royalties, in contrast to cash bonuses, involve no risk for the geothermal developer and are not a barrier against small developers. Royalties simply become part of production costs. With increased production costs, however, marginal resources become unproducible. This is a prime weakness of royalty charges. Increased costs and decreased production reduce the overall social value of geothermal resources, with the consuming public losing more than is gained by the public-as-resource-owner. The deleterious effect of royalties may be limited by employing only low rates; but low royalty charges fail to retain ownership value for lucrative geothermal reservoirs.[30]

Lease Terms and Adjustments

One method of limiting land speculation and losses due to unreasonable lease arrangements is to limit the effective life of a lease and to allow for adjustment of its various provisions. Primary lease terms of 5, 10 and 20 years have been selected by different states, allowing for renewal if producible geothermal resources are discovered during that period. Renegotiation of the lease typically is allowed after 20 years.

An important characteristic of geothermal resource development is the need for on-site use. This involves large capital investments in powerplant facilities and transmission lines which require 20 to 40 years for amortization. As previously noted, geothermal development is also incremental, progressively adding units of 55-110 MW. The prospect of lease termination or adverse adjustments within 5, 10 or even 20 years consequently figures quite differently in geothermal development than in development of other energy resources. Uncertain tenure due to short lease terms and frequent renegotiation compounds the risks already inherent to geothermal development, further deterring investment by risk-sensitive public utilities. The states may find, therefore, that these techniques of resource control are not appropriate to geothermal development.[31]

Modified Bidding

Geothermal reservoirs range widely from highly profitable dry-steam fields to clearly uneconomic low-temperature fields. Lease terms must therefore be flexible and equally wide-ranging to return a majority of ownership value to the public without suppressing development of marginal geothermal reservoirs.

Where bidding is warranted, cash bonus or profit shares are probably the best bid factors for achieving this balance.[32] As previously noted, however, bidding must be based on accurate knowledge of the resource.[33] State issuance of non-competitive exploration permits for lands with unknown potential, and competitive leasing for KGRA lands, is sound in this regard. Public loss occurs when permits may be non-competitively converted to leases.[34]

Arizona and **New Mexico** have attempted to reduce this loss by altering the requirements for bidding. In addition to known geothermal areas, tracts must be auctioned for which competitive permit or lease applications are filed. This procedure has also been adopted for federal geothermal leasing.

Unfortunately, such practice leads to bidding for unexplored, poorly assessed lands. As seen earlier, geothermal reservoirs cover large areas, and uncertainty in locating and estimating their actual dimensions forces prospectors to secure extensive acreage. Overlapping applications are therefore likely to contain large buffer areas of limited interest to the applicants.

This leasing method also encourages accumulation of large tracts of land prior to exploration. In this way, developers seek to avoid competitive applications by "free riders." Land will therefore be unnecessarily stockpiled. Also, with several developers following this strategy, overlap of applications may well occur for lands with negligible geothermal potential.

Even where overlapping applications include lands of real interest to developers, inherent uncertainty concerning reservoir potential, until proved through drilling, makes competitive bidding unenthusiastic. This holds true as well for "known" geothermal areas where there is no history of drilling.[35]

The same weakness characterizes even more the one-tiered leasing method established by **Montana** and **Washington**. These states do not grant exploration permits; access is achieved only by competitive bidding. This method is designed to eliminate free transfer of public resources, but lands of uncertain value draw minimal bids, perhaps from only a single bidder. The state will not capture the value of rich discoveries, and the general reduction of exploration (and subsequent development) due to delays and added costs for developers may exceed in value the small income gained from the sales.

One alternative to the arrangements already discussed is a two-tiered system with mandatory bidding for development rights. This approach was recently advanced in a Federal Trade Commission study of federal leasing policies.[36]

With this approach, development rights would be issued exclusively through bidding, but only for lands where geothermal resources had been proved through surface exploration and drilling. The explorer who discovers the resource would be credited a portion of the bid income, whether this was a cash bonus or profit shares.

Exploration rights probably should be exclusive for a given tract and would be distributed competitively or non-competitively. With non-competitive awards, the "explorer's credit" would be set in the permit. If exploration rights were auctioned, the permit would be awarded to the party bidding the *lowest* "explorer's credit." Reservoir potentials, estimates of exploration risk, and actual costs range widely; these facts favor competitive issuance of exploration permits. (Again, the credit is not a cash outlay, but a percentage interest in future income from the property, whether bonus bid or production income.)

With competitive bidding for all development rights, tracts permitted for exploration could be much larger than those presently granted, and without danger of land speculation. This could considerably improve the economics of exploration. To ensure diligent exploration, work plans could be required as a qualification for bidding. Unjustifiable departures from the plan would forfeit exploration rights and the "explorer's credit."

With bidding based on firm knowledge of reservoir potential, the public could be more confident of receiving fair value for its resources. Short lease terms and frequent renegotiations would be unnecessary. A primary lease term adequate for amortization of equipment, perhaps 40 years, would be appropriate. Larger lease areas would also be feasible.

In addition, with this method cash bonus bidding for leases could benefit exploration. Explorers could then anticipate returns (percentage of cash bonus) relatively soon after discovery, with income delays confined to less risky field development and plant construction. Geothermal investment would thereby be much more competitive with the other energy sectors.

Restricted capital availability and discounting of future income limit the size of cash bonus bids.[37] They tend as a result to reflect only the relatively near-term profitability of geothermal production. To compensate for these effects, leases could provide for a profit-sharing arrangement to begin, say, 15 - 20 years after initial production. By that date, accounting could be fairly restricted to the producing properties.[38] Profit-shares (or royalties, but these have adverse effects on production) would ensure that the public received its share of the future productive value of geothermal resources.

Conclusions

Several questions may be raised concerning a major revision of leasing methods. What are the costs in time and money of conversion to a new approach, and are they offset by the anticipated benefits? How assured are these benefits of being realized? How seriously may unforeseen complications cripple the proposed method?

These questions uncover major uncertainties when applied to the alternative leasing method discussed. It is

State	Primary Term	Renewal	Renegotiation of Rentals and Royalties
Alaska	10 years	one 5-year term if drilling; for duration of commercial production, up to 40 years	20-year intervals beginning 35 years after commercial production; and at end of first 40-year lease period
Arizona	5 years	2 years if drilling; for duration of commercial production	....
California	20 years	so long as geothermal resources are produced or capable of being produced in commercial quantities, up to 99 years	10-year intervals, beginning 20 years after lease date
Colorado	set in lease	for duration of commercial production; lacking production, at discretion of state land board	minimum royalty: 5-year intervals
Hawaii*	set in lease, not to exceed 65 years	....	5-year intervals, beginning 20 years after the lease date
Idaho	10 years	for duration of commercial production or drilling operations to at least 1000 feet, up to 40 years beyond primary term	....
Louisiana	at most 10 years	for duration of commercial production or development operations	....
Montana	10 years	for duration of commercial production or drilling	10-year intervals, beginning 20 years after lease date
Nevada	....	....	....
New Mexico	5 years	so long as geothermal resources are produced or capable of being produced in commercial quantities	10-year intervals, beginning 20 years after lease date
Oregon	10 years	10 years, if royalties in any year of preceding term equalled or exceeded annual rental due under lease; 5 years, if no production but discovery has been made or is deemed imminent; maximum of 50 years from lease date	....
Texas	(no lease terms established)		
Utah	10 years	for duration of commercial production; or 1-year terms, in absence of production, upon payment of $5/acre advance royalty	3-year intervals
Washington	5 years	so long as drilling with diligence; or upon commercial discovery, up to 20 years	....
Wyoming	10 years	so long as geothermal resources produced or capable of being produced in commercial quantities	10-year intervals

*Regulations not finalized

Fig. 62. State geothermal lease provisions

Annual Rental	Royalties	Acreage Limits
variable; $1/acre minimum	primary: 10-15% byproduct: 2-10% minimum: $2/acre/year	minimum lease: 640 acres maximum lease: 2,560 acres (5,750 for submerged lands) maximum state holdings: 25,600 acres
non-competitive lease: as set in lease competitive lease: $1/acre	primary: at least 12.5% byproduct: at least 12.5% shut-in: 4 times annual rental per year	maximum lease: 2,560 acres (4 sections) confined to 6 miles square
$1/acre	primary: 10% byproduct: between 2% and 10% minimum: $2/acre/year	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 25,600 acres (includes acreage under exploration permit)
set in lease	set in lease; minimum royalty incurred in advance of each 5-year period	....
state: as bid surface occupant: as agreed or set by Board of Land and Natural Resources	primary: 10% byproduct: 10%	maximum lease: 4 square miles (2,560 acres)
first 5 years: $1/acre second 5 years: $2/acre thereafter: $3/acre	primary: 10% byproduct: 5%	minimum lease: 40 acres maximum lease: 640 acres maximum state holdings: interest in 50 township-and-ranges
at least $1/acre or ½ cash bonus, whichever is greater	primary: at least 10% byproduct: at least 5%	maximum lease: 5000 acres
at least $1/acre	primary: at least 10% byproduct: between 2% and 5% shut-in: set in lease minimum: $2/acre/year	maximum lease: 640 acres
$1/acre	primary: 12.5% byproduct: 5.0%	....
$1/acre	primary: 10% byproduct: between 2% and 10% recreation or therapeutic: between 2% and 10% powerplant: 8% (net revenue) minimum: $2/acre/year	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 25,600 acres
years 1-3: $1/acre year 4: $3/acre years 5-10: $5/acre years renewed: $5/acre	primary: 10% byproduct: 1%, demineralized water; 5%, other (rentals paid each year deducted from royalties due)	minimum lease: 40 acres
(no lease terms established)		
$1/acre	primary: 10% byproduct: 10% (net proceeds)	minimum lease: 40 acres maximum lease: 640 to 2,560 acres, at discretion of director of state lands
at least $1/acre; at least $5/acre upon commercial production	primary: 10% byproduct: at least 4% (net proceeds) minimum: $5/acre/year	minimum lease: 40 acres maximum lease: 640 acres
$2/acre	primary: 10% byproduct: 5%	minimum lease: 640 acres maximum lease: 2,560 acres

uncertain whether small and large firms could both compete effectively under this leasing system.[39] Also, the procedure may fail in practice to protect the explorer. The method hinges on the ability of an "explorer's credit" to cover exploration investments. It is fully possible, however, that even the entire cash bonus bid for a lease would be insufficient to compensate the costs of discovery (Fig. 29).[40] As a result, explorers may need to bid royalty or profit-shares, rather than percentage of cash bonus; in that case, one anticipated benefit of the method evaporates.

The above considerations suggest that existing methods, or the best one among them, should be retained with modifications to circumvent identified weaknesses. Only if these steps prove inadequate should a major revision be attempted. Three important modifications which appear consistent with the public interest are listed below:

a) Make geothermal leases secure contracts for geothermal developers by ensuring lease extensions necessary to amortize capital investments. This does not exclude adjustment of royalties or profit-shares. Contracts for sale of geothermal resources will themselves provide for price adjustments. Well-defined conditions for lease adjustments should not be objectionable if they are reasonable, in a business sense, and do not depend on the unlimited and possibly capricious discretion of a single officer or agency.

b) Make any lease acreage limitations consistent with the realities of geothermal exploration and development. The need for extensive exploration and, in particular, drilling is a major fact of geothermal development. To encourage this investment, some amount of acreage, say 640-2560 acres, could be excluded from computations of total holdings for every exploration well drilled.[41]

c) Eliminate cash bonus bidding for geothermal resources where no strong geophysical evidence of commercial potential exists. In addition, where bidding is required, the benefits and limitations of other bid factors should be examined. California, for example, has prepared to lease property in The Geysers area by profit-shares bidding.[42]

DEVELOPMENT REGULATIONS

In each of the fifteen states, public agencies have been given the authority to regulate drilling and production of geothermal resources. These agencies are to ensure that geothermal resources are not wasted and that development operations do not needlessly degrade the land, water or other natural resource values of the state. For this purpose, most of the states have promulgated special regulations.

Common features of these regulations are required permits for each well drilled, converted, capped or abandoned; required drilling reports and well logs; and restrictions on the methods of handling drilling materials and well effluents. (Fig. 63) In addition, state air and water pollution control regulations apply to geothermal development. As a compliance surety, performance bonds must be filed (e.g., \$5,000 per well; \$25,000 per development), with the exact amount differing among the states. Hawaii, Idaho, and Oregon also require geothermal operations to be insured against liability.[43]

Reservoir Management

As a fluid resource, geothermal water and steam create special regulatory problems. Geothermal fluids migrate through the reservoir aquifer, and production from one well may drain large sections of the entire reservoir. Competing producers therefore are encouraged to increase present production. The cumulative result may be overproduction and the reduction of ultimate reservoir productivity. In addition, to increase the rate of production, operators must drill more wells than necessary for efficient production. Such excessive drilling creates more widespread environmental dislocation; it also significantly increases development costs. This means that fewer geothermal reservoirs will be developed, and the costs to the public, direct and indirect, will increase.[44]

To resolve this problem in petroleum reservoirs, well-spacing restrictions, direct production restrictions, and provisions for the unit operation of reservoirs have been used. The states have granted their geothermal regulatory agencies at least one of these powers. Statewide well-spacing requirements predominate, while production restrictions and mandatory unitization are techniques adopted by only a few states. (Fig. 64) As discussed below, however, for geothermal resources this pattern probably should be reversed, with emphasis placed instead on unit operation of reservoirs.

Well spacing. A spacing plan for wells sets the minimum distance allowed between a well and other wells, property lines and established roads or buildings. Spacing plans are prescribed alternatively in terms of minimum surface area per well (e.g., 40 acres/well). Well-spacing must also control directional drilling of wells to ensure that production zones correspond to the spacing array. (Fig. 65)

A spacing plan limits the number of wells that may be drilled into a reservoir. In this way the maximum rate of withdrawal from the reservoir is limited. The buffer zones created along property lines help secure correlative rights to the resource, and by restraining excessive drilling, a spacing plan also serves to limit environmental damage and the costs of development.[45]

In a petroleum reservoir, the most efficient well-placement has sometimes differed from a regular array.[46] The same number of wells with the same production rate may more effectively be concentrated in favorable reservoir locations. For geothermal wells, this is the usual situation, for unlike petroleum, geothermal water and steam produced at one point may have a different value than the same volume withdrawn at another reservoir location. As the fluid moves upward and laterally from a deep heat source, it gives up heat to its surroundings. The fluid flow may be maintained, but at increased distance from the reservoir hot spots, fluid temperature declines. Geothermal exploration is con-

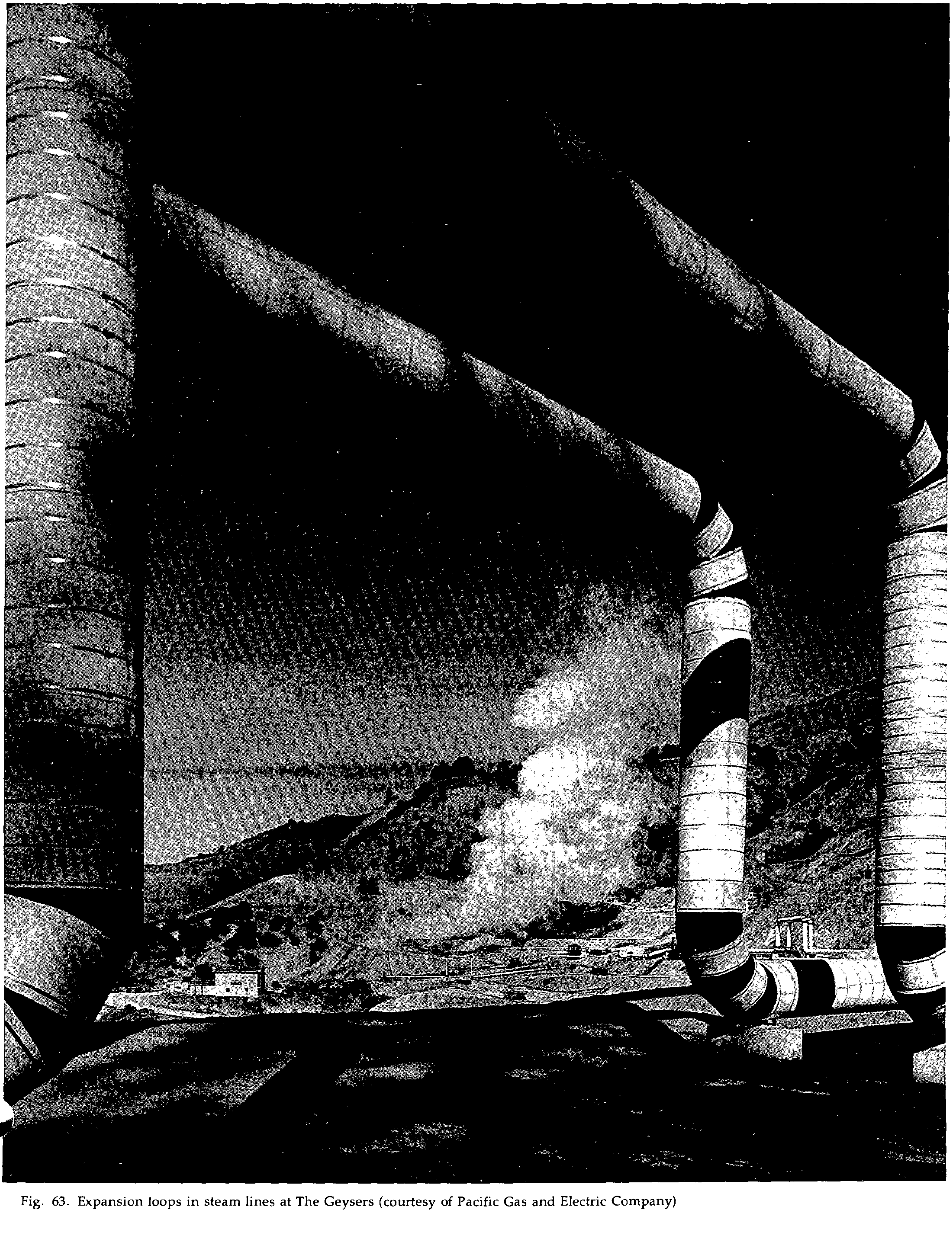


Fig. 63. Expansion loops in steam lines at The Geysers (courtesy of Pacific Gas and Electric Company)

cerned to find these hot spots which exist at the closest approach to the heat source or where the convective liquid arrives most directly and without dilution from the deep heat source.

The necessity of locating wells close to high-temperature areas indicates that well-spacing plans for geothermal resources need a different form than those for oil and gas. This is especially true since close spacing of geothermal wells may in some cases have little effect on well or reservoir productivity.[47] In general, well-spacing probably will be a less effective regulatory tool for geothermal reservoirs than it has been for petroleum.[48]

Pooling. If separate properties lie within an established well-spacing area, independent drilling of the properties will violate the minimum spacing requirement. To develop the area, the separate properties must be pooled and produced cooperatively, with costs accorded proportionate to the separate owners' share of the production. In addition, the party which undertakes actual production receives an operator's profit.

Since production is precluded without pooling, an incentive exists for voluntary pooling agreements. In some instances, however, voluntary pooling may be impossible. For example, one party, because of limited holdings, may need development in the divided area, while a second party with larger contiguous holdings may not want development. Instead, this party may prefer to drain the property by adjacent wells and thereby benefit from the other's undeveloped holdings. In such an instance, state mandated pooling may serve to protect correlative rights in a shared reservoir. (In so doing, the state must remain aware of the benefits accruing to the chosen operator.)[49]

Special problems may face a pooling arrangement for geothermal resources. In petroleum pooling, the produced resource can be divided equitably among the interest owners, who may then pipe it, truck it or store it. Geothermal resources cannot be handled in this way. Hot water and steam must be piped to a nearby point where the heat value is extracted, say in electrical generation. In this case, numerous wells are required to power the turbines, and the pooled area will contribute only a portion of the total required geothermal fluid.

Unless pooling is part of a more extensive cooperative agreement, one party will need in effect to buy the other owner's interest in the pooled area. One may therefore expect conveyance to predominate over pooling in geothermal reservoirs where well-spacing programs are in effect.

Production restrictions. Direct restrictions on the rate of withdrawal from a geothermal reservoir may be used to ensure the most efficient recovery of the resource. Direct control was first applied to petroleum production rates by a state agency in 1927. This action was subsequently upheld by the U.S. Supreme Court as a reasonable method to prevent physical waste.[50]

The regulatory agency first determines the maximum efficient withdrawal rate for a reservoir and then prorations production by area to the development interests.* Production may be allocated to wells in the reservoir, rather than to the areal holdings themselves, and in this case a coordinate well-spacing program is needed to block excessive drilling. Production restrictions are most effective, however, when they are guided by the characteristics of each particular reservoir.**[51]

State	Well-Spacing		Enforced Unitization	Production Restrictions
	Area	*Pooling*		
Alaska	OG	OG	OG	OG
Arizona	GR	GR	GR, OG	....
California	GR, OG	OG	OG	GR (only for state leases)
Colorado	GR, OG	GR, OG	OG	OG
Hawaii	....	....	....	....
Idaho	GR	GR	GR	....
Louisiana	OG	OG	OG	OG
Montana	OG	OG	....	OG
Nevada	....	....	OG	GR (water)
New Mexico	GR, OG	GR, OG	....	GR, OG
Oregon	GR	GR	GR, OG	GR
Texas	GR, OG	OG	....	OG
Utah	GR, OG	OG	....	OG
Washington	GR	GR	GR, OG	....
Wyoming	GR, OG	OG	....	GR (water), OG

GR = Geothermal Resources
OG = Oil and Gas

Fig. 64. Statewide regulatory powers

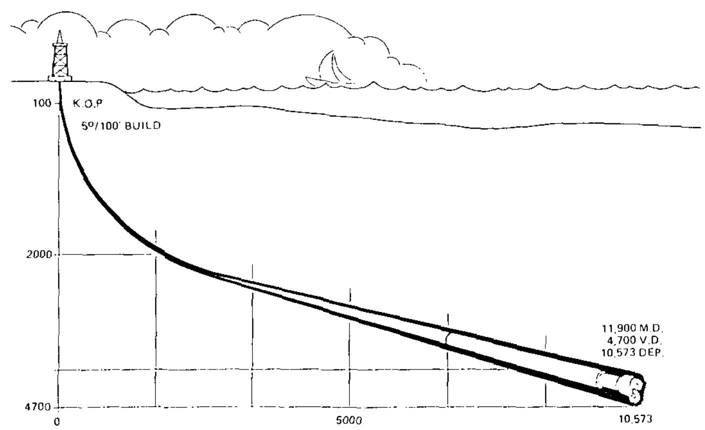


Fig. 65. Directional drilling with maximum deviation of 10,573 feet from vertical (from Garrison, "Directional Drilling," figure 4)

*The New Mexico Oil and Gas Conservation Commission, in protecting geothermal correlative rights, is directed when allocating production to take account also of unreasonable discrimination against reservoir interests through denial of access to geothermal resources transportation or utilization facilities. (Chapter 272, Sec. 10A; Laws of 1975)

**For geothermal resources Nevada, at this time, relies on water allocation procedures which involve production restrictions. The limitation of simple appropriative water rights is that correlative interests in a reservoir are vulnerable. Prior rights predominate, and this may encourage hasty and wasteful development.

Unitization. Unitization is an agreement between ownership interests to cooperatively develop a shared reservoir. A major goal of unitization is to increase the ultimate productivity of the reservoir. For geothermal development there is another very important benefit. Unit producers have a larger and more assured resource supply to offer.[52] Security of supply and volume is greatly enhanced, and this is a critical value to utility purchasers. This stronger bargaining stance increases the value to producers of geothermal development. The economic feasibility of constructing power transmission lines is also improved for larger holdings.

One form of unitization involves the merger of titles to the included property, with each lessee a co-tenant in every tract in proportion to the interest held in the entire unitized area. This form was common in early petroleum unit agreements, but has largely been replaced by agreements which pool production interests. With production pooling, the lessee retains full title to his tract but shares proportionally in development costs and production.[53]

The regulatory value of unitization is that it removes the competitive drive to overproduce the reservoir. With unitization each interest in the resource benefits from improved production efficiency. Proper well-spacing and production rates are actively pursued, rather than enforced by the state. The burden on the state regulatory agency consequently is greatly reduced. Performance in general increases since producers voluntarily use their full knowledge to eliminate waste, which is the regulatory goal.[54]

The agreement for unit development must settle several matters: 1) central management of development; 2) allocation of costs and income; 3) a general plan, including the number of wells, their location and rates of production; and 4) marketing arrangements.[55] These can be agreed upon only with extensive knowledge of the reservoir. In fact the impetus to unitize a reservoir will generally appear only after independent resource surveys and drilling have demonstrated competitive ownership of significant portions of the reservoir.[56]

The obstacles to voluntary unitization are in part those faced by any cooperative arrangement. Pride in independent control and unwillingness to contend with compromise are impediments to such agreements. Inherent advantage within the reservoir may encourage hold-outs. The financial and professional benefits of managing development can also make settlement of this function a problem. Management functions and associated perquisites may have to be distributed among the parties.[57]

Treatment of unit agreements under state and federal antitrust statutes and taxation codes should not deter unitization. Unit agreements for petroleum production have been widespread without antitrust complications. Over 60% of oil produced on federal leases comes from unitized operations. No unit agreement for petroleum production has been prosecuted under state antitrust laws.[58]

The states have helped ensure that such agreements are free from monopoly charges by requiring their approval by the regulatory agency. For geothermal unitization, prior approval is again required by the states. The federal Geothermal Steam Act specifically warrants unitization of federal leases with other tracts, and no state forbids unitization, whether of private, federal or state lands. This certification should continue to serve as assurance against antitrust prosecution.

A complication in this regard, however, is that geothermal unit operations will require cooperative marketing of the resource. This has not been true of petroleum operations; petroleum may simply be credited to the various interest owners to market as they choose.[60] In contrast, geothermal water and steam are not susceptible to such independent use. Once produced they cannot be stored, and in transport they rapidly lose their heat value (especially steam). Consequently, well production will necessarily be marketed as a whole and the proceeds from the sale distributed *pro rata*. This fact may make geothermal unitization more vulnerable to antitrust strictures, for it is on marketing that they bear most firmly.[61]

Unit agreements create a legal entity with some features of a corporation. The unit may make contracts, may bring suit and may be sued. The agreement is binding on each party, the party's heirs and assigns for the term of the agreement — usually the life of the reservoir. Nevertheless, the unit is not taxed as a corporation. Instead, each interest owner is responsible for state and federal income tax at the appropriate personal or corporate rate. The taxes are levied against the owner's share of the unit production. Further, deductions from net income, such as depletion allowance and intangible development costs, are proportionally allocated among the unit parties and applied to their separate incomes. Unitization therefore creates no tax disadvantages.[62]

Many impediments to unitization may be surmounted by diplomacy and factual determinations. On some occasions, however, obstacles may be intractable and a voluntary agreement will fail to occur. The public may nevertheless have an interest in promoting the unit operation of a reservoir. Unitization may be blocked by blind stubbornness or parties in a position without unitization to exploit the resource to the detriment of other resource interests.

To manage such instances, some states have granted their regulatory agencies the power to mandate unitization. A minimum percentage of ownership interests may need to voluntarily assent to an agreement before the state will mandate unitization (Arizona: 63%), but this proviso is not generally required.

When ordering unitization, the state takes upon itself the responsibility of ensuring that the various rights of the parties are protected under the agreement. The many adjustments and accommodations to special needs will require attention so that no unreasonable burdens result. To a large extent, the states have accepted this responsibility even for totally voluntary agreements. Voluntary agreements generally must be reviewed and certified on the basis of fairness to the parties and the benefits for resource production.[63]

The extra burden for a state in mandating unitization lies in the necessity to work with recalcitrant parties to formulate an acceptible agreement. This added responsibility should be weighed in the light of the several advantages of unitization. Increased efficiency of production benefits the entire public, and difficulties for the regulatory agency to enforce waste prevention are much reduced with unitization.[64] The weaknesses of pooling and well-spacing requirements for geothermal reservoirs also advance the importance of unitization for regulation of geothermal development. These considerations suggest that states generally should provide mandatory unitization as a tool for their regulatory agencies.

Environmental Protection

Like other industrial developments, geothermal development disturbs native habitats. Construction requires surface grading, excavation and materials hauling to and from development sites. Machinery and construction generate noise and various forms of air and water pollution.[65] Development also stresses local communities socially and economically. New population influxes may bring different values and lifestyles; they also demand social services — roads, schools, water, sewage and police protection — at an average cost for each newcomer of perhaps $5000 to $6000.[66]

Wherever new development is unacceptable, geothermal development will be unacceptable. Geothermal development at The Geysers, in Sonoma and Lake counties of California, has encountered this type of basic resistance. The Mayacamas Mountains offer recreation in a natural habitat, not only to local residents but to all of metropolitan San Francisco 90 miles away. Many persons feel that the potential and actual adverse effects of geothermal development are too great in this setting.[67] (Fig. 67)

Environmental hazards specific to geothermal development are 1) noise from well drilling and steam venting, 2) air pollution by vented gases, and 3) surface and groundwater pollution by drilling fluids and produced geothermal fluids. Land subsidence or seismicity from fluid production and injection also is a potential problem.

Noise pollution. Pipe racking, drive engines and air-drilling operations generate considerable noise. These activities are continuous during the months of field development. Field expansion, well replacement and re-boring prolong drilling operations at a reduced level throughout the lifetime of the field.

When a well penetrates a steam producing zone, it is cleaned and tested by venting to the atmosphere. This may generate sound levels of 120 dB(A) at 50 feet. With cyclonic mufflers, this noise can be reduced to 80-90 dB(A).[68] Noise levels of some familiar occurrences are compared with those of geothermal operations in Figure 66.

Source	Level
The Geysers Area	
Drilling operation (air) (25 ft)	126 dB(A)
Drilling operation (air) (1500 ft)	55 dB(A)
Muffled testing well (25 ft)	100 dB(A)
Muffled testing well (1500 ft)	65 dB(A)
Steam line vent (50 ft)	100 dB(A)
Steam line vent (250 ft)	90 dB(A)
Comparative Levels	
Jet aircraft takeoff (200 ft)	125 dB(A)
Threshold of pain	120 dB(A)
Unmuffled diesel truck (50 ft)	100 dB(A)
Street corner in a large city	75 dB(A)
Residential area at night	40 dB(A)

dB(A) Decibel value measured using the A weighting network of a standardized sound level meter.

Fig. 66. Noise levels at The Geysers and from familiar noise sources (from Futures Group, *Technology Assessment*, p.232)

Air pollution. Gases and aerosols released from geothermal steam and hot water can cause local contamination of the air. Ammonia (NH_3), arsenic (A), methane (CH_4), mercury (Hg), and hydrogen sulfide (H_2S) are commonly found in deep subsurface fluids, including oil and gas, geothermal steam and hot water. When producing these fluids, escape of contaminants to the air or water must be controlled.[69]

The most troublesome air pollutant from geothermal development is hydrogen sulfide. It may occur in significant quantities, and unlike most other air contaminants, hydrogen sulfide is not easily dispersed. A heavy gas, it tends to accumulate in valleys, as at The Geysers, and during temperature inversions. The average hydrogen sulfide content of *steam* at The Geysers is approximately 200-300 ppm (.02% - .033%); at Larderello, Italy, it is 490 ppm.[70] If concentrated, emissions at these levels can be hazardous.

For humans, 0.002% hydrogen sulfide *in air* is the short-term toxicity level.[71] Long-term effects may result from hydrogen sulfide induced acidosis. H_2SO_3 in the atmosphere can reduce the body's alkaline reserve; this disturbs bone growth in children and produces myocardial degeneration in adults. Also, vital lung capacity is reduced due to H_2S in the air.[72] At sufficiently high levels, hydrogen sulfide is a serious hazard. Short of that, it can still be an extreme nuisance. In miniscule amounts, H_2S is detectable as a "rotten eggs" odor.

Emissions occur when wells are vented and during the normal operation of some types of geothermal powerplants. Between penetration of the steam zone and connection to the powerplant, a well at The Geysers may release 20,000 pounds of hydrogen sulfide.[73] In dry-steam plants and flashed steam plants, hydrogen sulfide is released during plant operation. An uncontrolled 55 MW plant will eject some 900 tons/year.[74] If sufficiently dispersed, however, ambient H_2S concentrations will remain below established safety tolerances. In addition to dispersion, emissions from powerplants can be controlled by the use of separators and chemical scrubbers which remove the gas. This is the current practice of Pacific Gas and Electric at The Geysers.[75] Closed-cycle powerplants do not release fluid or air contaminants.

Water pollution. Brine discharges, failures of drilling fluid sumps, and erosion due to surface grading may all occur in geothermal development. Strict enforcement of standards for well placement and drilling minimizes water pollution from well blowouts and surface erosion. Sump failures may effectively be eliminated.[76]

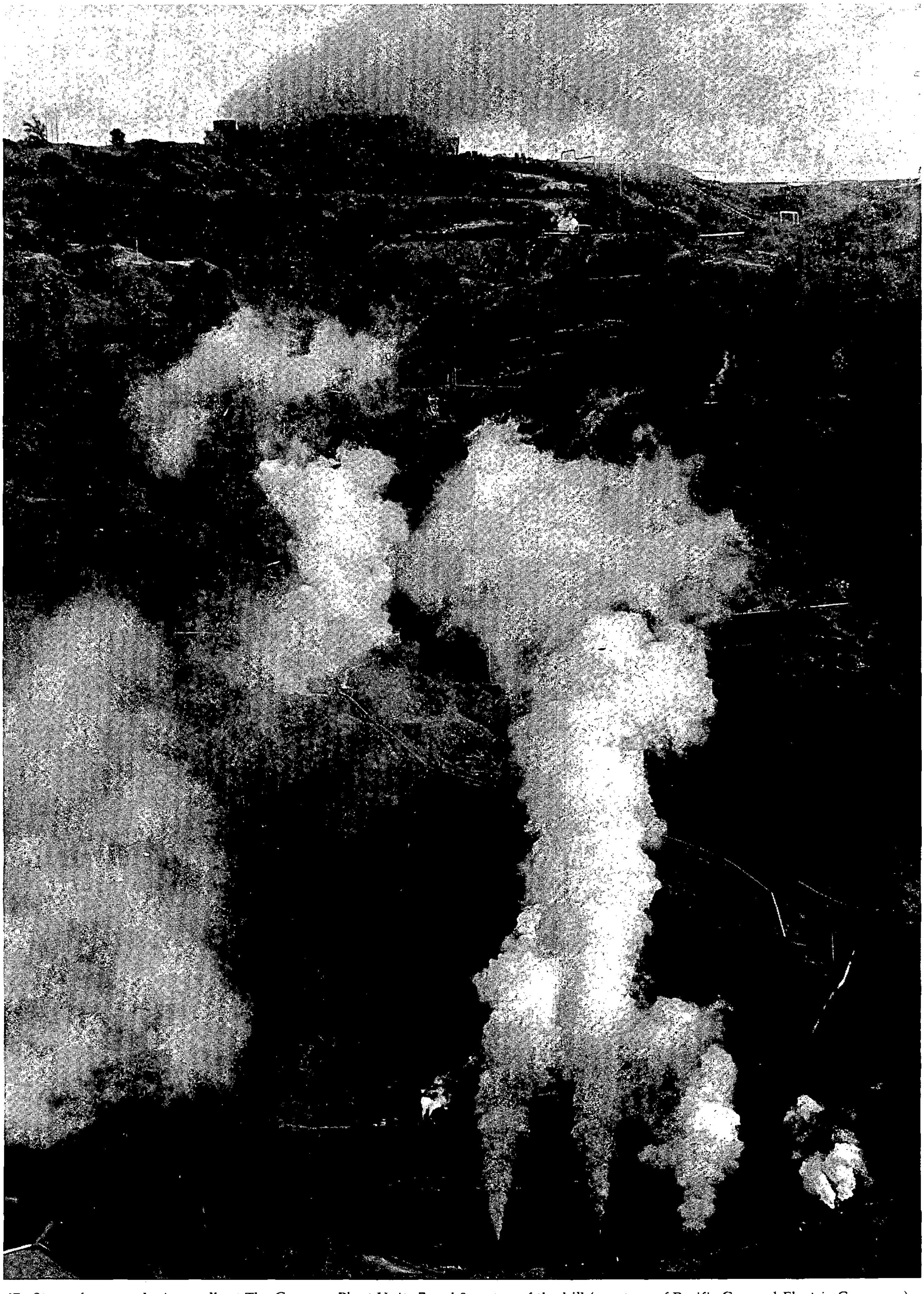


Fig. 67. Steam from producing wells at The Geysers; Plant Units 7 and 8 on top of the hill (courtesy of Pacific Gas and Electric Company)

Discharge of geothermal fluids to the surface may be unacceptable in many locations. (Fig. 68) A barrel of brine with 10% solids, or 100,000 parts per million (ppm), will raise 17,000 gallons of fresh water above the level safe for drinking (300 ppm).[77] Arsenic, mercury, or other constituents may be present in prohibitive concentrations.[78] In addition, fluid discharged from powerplants is still at temperatures near boiling. Its introduction to rivers or lakes in large volume may be extremely disruptive to aquatic habitats. In these instances, injection of the fluid to subsurface formations may be required. This is a common procedure in petroleum development. Texas wells in 1961 returned brine to subsurface strata at the rate of 6.6 million barrels/day; in Kansas the rate is 5 million barrels/day.[79]

Thermal pollution of water bodies may also occur with some powerplant cooling systems. This problem is avoided by use of cooling towers, and these generally are anticipated for geothermal powerplants.

Average ocean water	35,000 mg/ℓ
Recommended limit for drinking water	500*
Average in Salton Sea	38,000
Average of ground water in Imperial Valley	1,500
Average in Colorado River at present**	850
Average in Colorado River forecast for 2000 (without control measures)**	1,250
Average in Great Salt Lake, Utah	300,000
Geothermal water at Cerro Prieto, Mexico	13,000-25,000
Geothermal water at Butts geothermal domain, Imperial Valley†	260,000
Geothermal water elsewhere in Imperial Valley†	3,000-20,000 mg/ℓ

*State Department of Health will permit use of water of 1,500 mg/ℓ under a temporaty permit.

**At Imperial Dam where water is diverted for irrigating agriculture in Imperial Valley. Concentrations are based on U.S. Bureau of Reclamation study reported in "Colorado River Water Quality Improvement Program," Feb. 1972

†Based on available records

Fig. 68. Total dissolved solids of various waters in parts per million (ppm) or milligrams per liter (mg/ℓ) (from California Resources Agency, "Water and Power from Geothermal Resources," table 1)

Subsidence and seismicity. Unlike air, water and noise pollution, subsidence and seismicity are not problems inherent to geothermal development. They are not hazards generally associated with dry-steam reservoirs. In water-dominated systems, subsidence or seismicity may or may not occur depending on the reservoir's rock structure and fault characteristics.[80] The severity of such occurrences similarly corresponds to particular conditions. As a general concern, it is most serious for development of geopressured reservoirs along the gulf coasts of Texas and Louisiana.[81]

Oil and gas development has contended with these problems for many years. One serious occurrence was at the Wilmington field which partly underlies Los Angeles and Long Beach Harbor. By 1958, subsidence had reached 25 feet at the center of the affected area. Damage to surface structures and harbor facilities was estimated at that time to be $90 million. The California Subsidence Act of 1958 was required to permit unitization agreements necessary for a pressure maintenance program. Since 1959 injection of fluid has successfully maintained reservoir pressure and controlled subsidence.[82]

Fluid injection is the main tool for subsidence control. The technology of underground disposal and pressure maintenance was well developed and widely known by the end of World War II. State regulatory agencies have given it great attention since the late 1960s.[83]

Conclusions

Irresponsible geothermal operations can pose clear dangers to public health and local environments. Each of the states has established regulatory agencies to eliminate such actions. Geothermal operators must obtain permits to site and drill wells. Methods for well drilling, casing and cementing are prescribed to protect underground aquifers and prevent blowouts. Production and disposal techniques must be approved, and permits are required to plug and abandon a well. State air and water pollution standards control noxious emissions. Geothermal powerplants and transmission lines are sited and regulated like other electric generation facilities. Surety bonds must be filed to insure compliance at each stage.[84]

Nevertheless, geothermal development carries with it impacts on air and water resources, on flora and fauna, and on local communities which cannot be completely eliminated. The presence of geothermal wells and powerplant alters the site. But these effects must be weighed and balanced against the benefits of geothermal power. These benefits include not only useful electrical and heat energy (and tax revenues), but also the reduction of alternative power projects. Uranium and coal stripmining, off-shore drilling and oil-tanker deliveries, coal-fired and nuclear powerplants, and disposal or reprocessing of nuclear wastes have their own undesirable consequences. They produce air and water pollution, disrupt the land surface and wildlife habitats, consume water resources, and pose hazards to the public health. Moreover, these effects are often more serious and widespread than would result from geothermal projects supplying the same energy needs.[85] Geothermal development has comparatively minor, localized impacts. This fact is an important consideration when judging the relative merits of our various energy alternatives.

Notes

1) Donald B. Elmer and Kathryn E. Rogers, "Legal Issues in the Development of Geopressured-Geothermal Resources of Texas and Louisiana Gulf Coast," p.1.
2) Donald Allen, "Legal and Policy Aspects of Geothermal Resource Development," pp.250-252.
3) Compare, for instance, New Mexico's treatment of geothermal resources on the pattern of oil and gas with Utah's or Nevada's treatment of geothermal resources as water.

4) Hawaii: H.B.2197-74 (1974) amending Chapter 182, Government Mineral Rights;
Idaho: Section 42-4002 and Section 47-1602 (added 1972);
Montana: Section 81-2602 (1974);
Washington: Sub.H.B. 135 (1974) adding Title 79, Chapter 76; see Section 4;
Wyoming: Section 41-121.

5) See IDAHO CODE, Section 47-1602; and
Robert M. Kamins and Donald Kornreich, *Legal and Public Policy Setting for Geothermal Resource Development in Hawaii*, pp.37-38.

6) 100-10-103(6c), COLORADO REVISED STATUTES 1963 as amended.

7) CALIFORNIA PUBLIC RESOURCES CODE, Division 6, Part 2, Chapter 3, Article 5.5 (6903) (added by Geothermal Resources Act of 1967, Ch.1398, Stats. 1-67);
Federal Geothermal Steam Act, P.L. 91-581, Section 2. (See Appendix 4)

8) Larry J. Garside, "Geothermal Exploration and Development in Nevada through 1973," p.8.

9))S.B. 158 (1975), adding Section 2-5, Title 48, NEVADA REVISED STATUTES as amended.

10) Washington Sub. H.B. 135, Sections 3, 6, 10 (Chapter 76, Title 79 RCW).

11) See discussion of federal and state laws in Elmer and Rogers, "Legal Issues," pp.38-68.

12) Title 30, Chapter 8, Section 801, LOUISIANA REVISED STATUTES of 1950 as amended (Act 784, 1975).

13) Texas S.B. 685, Section 3 (Texas Geothermal Resources Act of 1975).

14) See Elmer and Rogers, "Legal Issues," pp.51, 60.

15) ARIZONA REVISED STATUTES, Section 27-651 (5,10) (added by Laws 1972, Ch. 152, Section 2).

16) Oregon H.B. 2040 (1975), Sections 3(3,7), 4, and 35(7), amending ORS 522 and ORS 537.515.

17) Elmer and Rogers, "Legal Issues," p.42.

18) CALIFORNIA PUBLIC RESOURCES CODE, Chapter 4, Division 3, Section 3742.2.

19) For an example, see Elmer and Rogers, "Legal Issues," pp.75-76.

20) Calculated from Figure 27 (infra).

21) Douglas H. Cortez, Ben Holt and A. J. L. Hutchinson, "Advanced Binary Cycles for Geothermal Power Generation," pp.89-90.

22) Joseph Aidlin: Oral Communication;
also, see Elmer and Rogers, "Legal Issues," p.100.

23) See Christopher D. Stone and Joseph W. Aidlin, eds., *Proceedings of the Conference on Geothermal Energy and the Law*, pp.58-59;
also, see Christopher D. Stone and Jack McNamara, *Geothermal Energy and the Law*, Vol. I, pp.237-247.

24) FTC Bureaus of Competition and Economics, *Report to the Federal Trade Commission on Federal Land Policy*, pp.221-303.

25) Stone and McNamara, *Geothermal Energy and the Law*, pp.183-187.

26) The cost of power generation is near-optimum for units of 55-110 MW. To this cost, however, must be added the cost of delivering power to the user. Large fixed costs for construction of transmission facilities will greatly increase the price of power from a small capacity field. Therefore the minimum capacity of a field feasible for development will depend on its location as well as the price of power from competitive sources. These conditions may vary greatly. In rural Alaska, for example, where the price for fuel oil exceeds $1 *per gallon*, small unit geothermal development may be economically attractive, even though the marginal cost of power is not nearly optimum. See, R. B. Forbes et al., *Utilization of Geothermal Energy Resources in Rural Alaskan Communities*, pp.7,8,14,24-26.

27) Frederick M. Peterson, "Two Externalities in Petroleum Exploration," pp.101-113;
also, see Stone and McNamara, *Geothermal Energy and the Law*, pp.185-186.

28) Robert Greider, "Status of Economics and Financing Geothermal Energy Power Production," p.13.

29) Peterson, "Two Externalities in Petroleum Exploration," pp.106-107;
Joseph Aidlin: Oral Communication;
Stone and Aidlin, eds., *Conference on Geothermal Energy*, pp.13,17,30,32.

30) FTC, *Federal Land Policy*, pp.263-278;
also, see Honorable Frederick Fishman, "Memorandum," in *Conference on Geothermal Energy*, eds. Stone and Aidlin, p.47.

31) Stone and Aidlin, eds., *Conference on Geothermal Energy*, pp.21,72-73;
Stone and McNamara, *Geothermal Energy and the Law*, pp.189-197.

32) FTC, *Federal Land Policy*, pp.89-202.

33) Ibid., pp.246-250. See previous discussion of risk and land costs in exploration.

34) This was the judgement of the Public Land Law Review Commission concerning all natural resource lands. *One Third of the Nation's Land*, A Report to the President and to the Congress by the Public Land Law Review Commission, 1970. See discussion in Stone and McNamara, *Geothermal Energy and the Law*, pp.109-124.

35) Bidding at The Geysers has averaged over $800/acre. In other KGRAs, bidding has been less than 1/10 this amount. For all federal geothermal lease sales, bidding has averaged approximately $70/acre. The number of bidders interested in poorly explored areas is also lower. Many tracts in "known" geothermal areas receive only one bid, or none at all. U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975; idem, "Geothermal Lease Bid Record";
Stone and McNamara, *Geothermal Energy and the Law*, pp.83-88.

36) FTC, *Federal Land Policy*, pp.725-744.

37) Ibid., pp.246-250, 730.

38) Since investment in producing geothermal properties includes the cost of discovery, accounting can be a major roadblock to equitable profit-sharing arrangements. After 15-20 years, however, discovery costs will have been amortized and accounting may reasonably be restricted to expenditures and income for the producing properties. For leases within well-explored, established reservoirs, as at The Geysers, accounting may also be restricted initially to the producing property. California, for example, has prepared to lease state geothermal rights at The Geysers through profit-shares bidding with accounting restricted to the leased properties. See, California State Lands Commission, "Geothermal Resources Lease, Exhibit C: Net Profits Account, Accounting Procedures."

39) Ronald Barr, Earth Power Corporation: Oral Communication.

40) Bonuses of $800/acre are sufficient to repay at most $6 million in discovery expenditures on 7500 acre tracts. As seen earlier (Figure 29), statistical costs may actually be double this figure.
See also Stone and McNamara, *Geothermal Energy and the Law*, pp.54-62.

41) Joseph Aidlin: Oral Communication.

42) See note 38 above; Stone and Aidlin, eds., *Conference on Geothermal Energy*, p.71;
Stone and McNamara, *Geothermal Energy and the Law*, pp.113-125.

43) See Appendix 2 for a more detailed description of development regulations.

44) Geothermal resources share this fluid character with petroleum resources. The implications for regulation of geothermal development discussed here are based on Stephen L. McDonald's study of petroleum regulations in *Petroleum Conservation in the United States*.

45) McDonald, *Petroleum Conservation*, pp.45, 150.

46) Ibid., pp.183-185.

47) Russell James, "Optimum Well-Spacing for Geothermal Power";
Abt Associates, Inc., *Energy Fuel Mineral Resources of the Public Lands*, p.E7.

48) Keiji Matsuo, "Drilling for Geothermal Steam and Hot Water," p.82.

49) Donald Finn, Geothermal Energy Institute: Oral Communication.

50) McDonald, *Petroleum Conservation*, pp.36-37.

51) Ibid., p.47, 187.

52) This is also true of petroleum development; Ibid., p.209.

53) Ibid., p.199.

54) Ibid., pp.197-198.

55) Ibid., p.201. The federal geothermal development regulations (30 CFR 271.12) give a standard agreement for unit operations; see Appendix 2.

56) Ibid., pp.25, 200. This fact implies that well-spacing for early development of shared fields should be very wide so that the need for unitization will be realized before excessive drilling occurs; Ibid., p.25.

57) Ibid., pp.213-216; p.200.

58) Ibid., pp. 51, 199, 210, 245; Abt Associates, Inc., *Energy Resources*, B155.

59) P.L. 91-581, Section 18.

60) McDonald, *Petroleum Conservation*, p.201.

61) Ibid.

62) Ibid., p.199.

63) This pattern was set in petroleum agreements; Ibid., p.244.

64) Ibid., p.226.

65) C. Richard Schuller et al., *Draft of a Report on Legal, Institutional, and Political Problems in Producing Electric Power from Geothermal Resources in California*, p.53.

66) Thomas S. Kleppe, "Remarks of Secretary of the Interior Thomas S. Kleppe before the Third Annual North Dakota Water Conference — Fargo, North Dakota, Feb. 18, 1976."

67) Schuller et al., *Draft of a Report*, p.49.

68) Ibid., p.50.

69) Ibid., p.53; Futures Group, *A Technology Assessment of Geothermal Energy Resource Development*, pp.229-232.

70) Futures Group, *Technology Assessment*, p.229. Concentrations of H_2S in steam encountered at The Geysers have been as great as 1600 ppm (.16%); see John P. Finney, "Design and Operation of The Geysers Power Plant," p.148.

71) Futures Group, *Technology Assessment*, p.229.

72) Andrzej Frontczak, "The Effect of the Kind of Respiration and of the Air Irritating the Respiratory Tract on the Vital Capacity of the Lungs."

73) Schuller et al., *Draft of a Report*, p.51.

74) Ibid., p.83. At The Geysers, two-thirds of H_2S emission comes from the cooling towers and the rest from gas ejectors for the turbines. Finney, "Geysers Power Plant," p.158.

75) Futures Group, *Technology Assessment*, p.229;
Gordon W. Allen and H. K. McCluer, "Hydrogen Sulfide Emissions Abatement for The Geysers Power Plant."

76) Schuller, *Draft of a Report*, pp.51-52.

77) "Oilfield Pollution and What's Being Done About It," *Oil and Gas Journal*, Vol.61 (Je 24, 1963), p.77.

78) Robert C. Axtmann, "Chemical Aspects of the Environmental Impact of Geothermal Development."

79) "Oilfield Pollution," p.77.

80) Richard G. Bowen, "Environmental Impact of Geothermal Development," pp.201-205.

81) Eugene Herrin and Tom Goforth, "Environmental Problems Associated with Power Production from Geopressured Reservoirs," pp.311-320;
Stavros S. Papadopulos, "The Energy Potential of Geopressured Reservoirs: Hydrogeologic Factors," pp.185-187;
Charles W. Kreitler and Thomas C. Gustavson, "Geothermal Resources of the Texas Gulf Coast — Environmental Concerns Arising from the Production and Disposal of Geothermal Waters," pp.25-49.

82) McDonald, *Petroleum Conservation*, p.142.

83) Ibid., pp.143,145.

84) See Wapora Inc., *Survey of Environmental Regulations Applying to Geothermal Exploration, Development, and Use*, Phase I, Draft Interim Report.

85) Bowen, "Environmental Impact of Geothermal Development," pp.197-214.

Appendix 1
State Laws and Regulations Regarding Geothermal Resources

Alaska
State Law: 38.05.181 (1971)
Leasing Regulations: 11 AAC 84.700 to 84.720 (1974)
Drilling Regulations: 11 AAC 94.730 (1974)
Geothermal regulations refer to general mineral leasing procedure (Chapter 82). All regulations and law compiled in "Regulations and Statutes Pertaining to Coal and Other Leasable Minerals on Alaska Lands as Contained in the Alaska Administrative Code and the Alaska Statutes," Division of Lands, Department of Natural Resources, State of Alaska, September 1974.

Arizona
State Law: Art. 4, Sec. 27-651 to 27-666 (Ch.152, Laws 1972)
Leasing Regulations: Land Department Regulations, Chapter 5, Article 21 (R12-5-801 to 811)
Drilling Regulations: "General Rules and Regulations Governing the Conservation of Geothermal Resources," Oil and Gas Conservation Commission (Title 27, Ch.4, Art.21), 1972.

California
State Law and Leasing Regulations: "Geothermal Resources Act of 1967," Public Resources Code, Div.6, Part 2, Ch.3, Article 5.5 (6902-6925) (Statutes of 1967, Ch. 1398)
Drilling Regulations: PRC, Div.3, Ch.4. California Laws for Conservation of Geothermal Resources. (Oil and Gas Publication #PRCO2)

Colorado
State Law: "Colorado Geothermal Resources Act (1974)," Section 1, Ch. 100, Article 10, Colorado Revised Statutes — 1963 as amended.
Leasing Regulations: State Board of Land Commissioners
a) "Special Rules and Regulations Relating to Geothermal Resources Leases" (Form #248-1) 1972; b) "Lease Form" (Form #248-2) 1972
Drilling Regulations: (pending) Department of Natural Resources, Oil and Gas Conservation Commission

Hawaii
State Law: Ch. 182 (Government Mineral Rights) as amended (H.B. 2197-74)
Leasing and Drilling Regulations: "Regulation of Geothermal Mining on State Lands and Reserved Lands in Hawaii" (DRAFT)

Idaho
State Law: "Idaho Geothermal Resources Act (1972)," Idaho Code Sections 42-4001 to 42-4015 (amended 1974); Sections 47-1601 to 47-1611 (1972)
Leasing Regulations: "Rules and Regulations Governing the Issuance of Geothermal Resources Leases," Board of Land Commissioners, 1974
Drilling Regulations: "Drilling for Geothermal Resources: Rules and Regulations and Minimum Well Construction Standards," Department of Water Resources, 1975

Louisiana
State Law: "Louisiana Geothermal Resources Act," Title 30, Chapter 8 (Act 784; 1975); "Louisiana Geothermal and Geopressured Energy Research and Development Act," Title 30, Part VI, Chapter 7, Subpart A (Act 735; 1975)
Leasing Regulations: (pending) State Mineral Board
Drilling Regulations: (pending) Department of Conservation

Montana
State Law: Sections 81-2601 to 81-2613 (Ch. 111, Laws of 1974); Section 60 (amended 1975, S.B. 79); Section 70-820 (amended 1975, H.B. 581)
Leasing Regulations: "Geothermal Rules and Regulations," Title 81, Chapter 6, Montana Administrative Code, 1975
Drilling Regulations: "Geothermal Investigation Reports," 36-2.8 (14), Montana Administrative Code

Nevada
State Law: Title 48, Sections 2 to 5 (S.B. 158; 1975); Sections 322.030 to 322.060 (A.B. 158; 1975)
Leasing Regulations: (Leasing moratorium on state lands since 1967)

Drilling Regulations: (Geothermal regulations pending) State Water Law and well drilling regulations

New Mexico

State Law: "Geothermal Resources Act," 7-15-1 to 7-15-28 (Chapter 158, Laws of 1967); "Geothermal Resources Conservation Act" (Chapter 272, Laws of 1975); 72-20-5(D) (Chapter 289, Laws of 1975)

Leasing Regulations: "Rules and Regulations Relating to Geothermal Resources Leases," State Land Office, 1971

Drilling Regulations: "Geothermal Resources: Rules and Regulations," Oil Conservation Commission, 1974

Oregon

State Law: H.B. 2040; 1975 (amending 1971 "Geothermal Resources Act"); H.B. 3185; 1975 (geothermal heating districts)

Leasing Regulations: "Geothermal Lease Regulations," 75-010 to 75-605, Division of State Lands (Revised 1975)

Drilling Regulations: "Geothermal Regulations," Ch. 632, Div.2 (20-005 through 20-170), *Oregon Administrative Rules Compilation;* 1972. (Department of Geology and Mineral Industries)

Texas

State Law: "Geothermal Resources Act of 1975" (S.B.685; 1975)

Leasing Regulations: (pending) State Land Office, School Land Board

Drilling Regulations: "Rules and Regulations Governing Drilling and Producing on Permanent Free School Lands," School Land Board, 1974.

"Rules Having Statewide General Application to Oil, Gas, and Geothermal Resource Operations within the State of Texas," (051.02.02.000 to 051.02.02.080), Texas Railroad Commission, Oil and Gas Division, 1976.

Utah

State Law: Sec. 73-1-20 (Ch. 189; Laws of 1973)

Leasing Regulations: "Rules and Regulations Governing the Issuance of Mineral Leases," State Land Board, 1973; "Geothermal Steam Lease and Agreement" (1973) (The lease form contains the regulations)

Drilling Regulations: "Rules and Regulations of the Division of Water Rights for Wells Used for the Discovery and Production of Geothermal Energy in the State of Utah" (DRAFT, 1975)

Washington

State Law: "Geothermal Resources Act" (Sub. H.B. 135; 1974)

Leasing Regulations: "Geothermal Leasing Policy," Department of State Lands (DRAFT, 1975)

Drilling Regulations: "Geothermal Rules and Regulations," Department of Natural Resources (DRAFT, 1975)

Wyoming

State Law: Title 41, Ch.2, Art.9 — "Underground Water" — Sec. 41-121 amended in 1973 to include "hot water and geothermal steam" as underground waters.

Leasing Regulations: "Rules and Regulations Governing the Issuance of Geothermal Resource Permits and Leases," State Board of Land Commissioners, 1975.

Drilling Regulations: (pending) Oil and Gas Conservation Commission

Appendix 2
Federal Geothermal Leasing and Development Regulations

ACCESS TO FEDERAL LANDS

The Geothermal Steam Act of 1970 (P.L. 91-581) authorized the Secretary of the Interior to issue leases for the development of geothermal resources. Lands available for leasing include (1) public, withdrawn and acquired lands administered by the Secretary; (2) national forest and other lands administered by the Department of Agriculture through the Forest Service; and (3) lands which have been conveyed by the U.S. subject to reservation of the geothermal steam and associated geothermal resources therein. Lands excluded from leasing include national recreation areas; lands in a fish hatchery administered by the Secretary of the Interior, wildlife refuge, game range, wildlife management area, waterfowl production area; lands acquired or reserved for the protection and conservation of fish and wildlife that are threatened with extinction; and tribally or individually owned Indian trust or restricted lands, within or without the boundaries of Indian reservations.

If lands to be leased are within a Known Geothermal Resources Area (KGRA), they are leased competitively to the qualified applicant offering the largest cash bonus bid. Lands outside of KGRAs are leased non-competitively to the first qualified applicant.

The KGRA designation is given to lands in which "the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary [of the Interior], engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose." A discovery is a well capable of producing geothermal resources in commercial quantities, which means quantities sufficient to provide a return after all variable costs of production have been met. If the geologic structure is not known, lands within five miles of the discovery are "nearby." If the extent of the producing structure is known, all land in the structural area, regardless of distance from the discovery well, is designated KGRA.

All of the lands covered by a geothermal lease application are designated KGRA if 50% or more of the lands overlap another application of the same filing period. If less than half of an application is overlapping, the competitive portion alone may be designated KGRA.[1] January of 1974 was the first application filing period. Subsequent filing periods begin on the first working day of each calendar month and end at the close of the last working day of that month.[2]

Regulations governing access to federal geothermal lands appear as Title 43, Chapter II of the Code of Federal Regulations (43 CFR Part 3200).

Pre-Lease Exploration

Examination of federal lands which involves only "casual use" requires no permits and may be conducted after notifying the Geothermal Supervisor of Geological Survey. Casual use involves activities which do not appreciably disturb the land, improvements or other resources, which do not require heavy equipment or explosives, and which confine vehicles to established roads.[3]

To drill temperature holes, construct roads and perform other intensive exploration, an operator must first secure approval under a "Notice of Intent and Permit to Conduct Exploration Operations." Geochemical and geophysical surveying and test drilling up to 152 meters (500 feet) may be conducted under this permit. Core drilling and geothermal development wells are not included; these are authorized only under a geothermal lease.[4] Casual use and explorations under a Notice of Intent are not exclusive rights and do not confer any preferential right to a geothermal lease.

Geothermal Leases

Before lands may be offered for lease, the Director of Geological Survey first secures a description of the lands and the effects on the area which might accompany geothermal development. If issuance of leases may significantly affect the quality of the human environment, an environmental impact statement must be prepared under the National Environmental Policy Act of 1969. The scope of such impacts to be considered includes fish and other aquatic resources, wildlife habitats and populations, aesthetics, and the area's recreational values.

In selecting tracts for lease, the Director is to request the views and recommendations of appropriate federal agencies, business and industry, and private organizations. Public hearings may be held. If a decision to lease is made, the Director is to include in the lease any special conditions necessary to protect the environment, to permit use of the land for other purposes, and to protect other natural resources.[5]

The special provisions are supplemental to the basic conditions of federal (competitive and non-competitive) leases. These standard conditions relate to the length of the lease, responsibilities incurred by the lessee, and benefits accruing to the federal government.

The first term of the lease extends for ten years and carries a requirement for diligent exploration. To qualify as diligent, operations must be approved by the Supervisor and proof of all expenditures submitted for review. In addition, after the fifth year, annual exploration expenditures must at least equal twice that year's rental payment. Provision is made, however, for crediting to later years all expenditures during the first five years, and that portion of expenditures during subsequent years which is in excess of the minimum. The minimum rental is $1/acre, escalating by $1/acre each year beginning with the sixth.

"If geothermal steam is produced or utilized in commercial quantities within the primary term of a lease, that lease shall continue for so long thereafter as geothermal steam is produced or utilized in commercial quantities." The phrase "produced or utilized in commercial quantities" means that one or more wells capable of commercial production have been established and a "bona fide" sale of the "steam" for delivery within 15 years has been signed.[6] The language of the regulations is in terms of "geothermal steam." Presumably, hot water production should also qualify; the exception is commercial demineralization of water, which is considered a byproduct.[7] Production of byproducts alone will qualify a lease for at most a 5-year continuation.[8]

Other basic conditions of leases concern acreage limitations, rentals, royalties, surety bonds, lease adjustments, required production of byproducts, pollution control, surface rights, suspension of operations, conveyance, inheritance, and numerous other particulars. Some of these are presented below.

Lease Terms:
- a) 10-year term
- b) renewal so long as commercial production occurs
- c) 40-year maximum for automatic renewal
- d) preferential right to second 40-year term

Acreage Limitations:
- a) 640 minimum
- b) 2560 maximum
- c) 20,480 acres/state maximum total holdings
- d) acreage committed to cooperative development plans is excepted when calculating total holdings within a state

Rental:
- a) $1/acre minimum (exact amount set in lease)
- b) $1/acre escalation each year after the fifth, until commercial production begins
- c) exploration expenditures during the first five years, and those exploration expenditures in excess of the minimum for subsequent years, may be credited to the escalated portion of rent due[9]
- d) $2/acre during periods of production

Royalties:
- a) at least 10% and no more than 15% on the "value of steam, or any other forms of heat or energy"
- b) no more than 5% of the value of byproducts sold, utilized or reasonably susceptible to utilization; except
- c) any byproduct which is a mineral named in Section 1 of the Mineral Leasing Act of 1920, as amended (20 USC 181), has a royalty as set in that act
- d) $2/acre minimum royalty commencing the year production in commercial quantities begins; this royalty is paid in lieu of rent
- e) 22½% maximum royalty

Lease Adjustments:
- a) rentals and royalties may be adjusted every 20 years, beginning 35 years after production of geothermal steam; maximum increase for any interval is 50%
- b) other terms and conditions may be adjusted at 10-year intervals, beginning 10 years after production of geothermal steam

Required Byproduct Production:
- a) the Supervisor will require the beneficial production of valuable byproducts, including demineralized water[10] except where:
  - i) beneficial production or use is not in the interest of conservation of natural resources;
  - ii) beneficial production or use would not be economically feasible; or
  - iii) beneficial production and use should not be required for other reasons satisfactory to the Supervisor[11]
- b) primary production of demineralized water is forbidden where such use would result in "undue waste" of geothermal energy[12]

Pollution Control and Unit Agreements:

The lessee is to conform to federal, state and local regulations concerning pollution.[13] Various specifics concerning operations under a lease, including unit agreements, are outlined in the regulations. These requirements also appear in Title 30, Chapter II, which sets out the regulations governing geothermal development operations. These regulations are cross-referenced in the lease regulations; they are discussed below.

Bonds:
- a) lease compliance: $10,000
- b) surface protection: $ 5,000
- c) in lieu of the above bonds, statewide or nationwide bonds may be filed
  - — statewide: $50,000
  - — nationwide: $150,000

GEOTHERMAL OPERATIONS ON FEDERAL LANDS

Issuance of a federal geothermal lease is necessary to drill and produce geothermal resources from federal lands. Development operations are governed by Title 30, Chapter II of the Code of Federal Regulations.[14] The regulations were adopted pursuant to Section 24 of the Geothermal Steam Act which directs the Secretary of the Interior to prescribe such rules and regulations as are necessary to protect the public interest, prevent waste, protect water quality and other environmental qualities, and to conserve geothermal resources and other natural resources. The director of the U.S Geological Survey administers the regulations through the Chief of the U.S.G.S. Conservation Division or the Chief's appointed representative, the Area Supervisor.

Waste is defined by the regulations as 1) physical waste, 2) waste of reservoir energy, 3) the location, spacing, drilling, equipping, operating, or producing of any geothermal well in a manner which causes reduction in the ultimate recovery of geothermal energy from a reservoir, and 4) the inefficient transmission of geothermal energy from source to point of use.[15] To prevent such waste and to protect the quality of the environment, the Supervisor will issue any necessary Geothermal Resources Operational (GRO) orders supplementary to Title 30.

Plan of Operations

Before commencing any operations on the leased land or lands committed to a unit agreement, the lessee must present a plan of operations for approval.[16] The first requirement is a collection of data concerning the existing air and water quality, noise, seismic and land subsidence activities, and ecological systems of the lands. This information base for the local environment must cover a period of at least one year prior to the submission of a plan for production.

The plan of operations must also indicate the planned location of wells, mud tanks, reserve pits, cooling towers, pipe racks, access roads, camp sites, air strips and other potential surface disturbances. Sources of water and road building materials, topographic features of the land, and intended methods of waste disposal must be described.

A narrative statement is required specifying measures to be taken for protection of the environment. Fires, soil erosion, surface and ground water pollution, fish, wildlife and other natural resources, air and noise pollution, and hazards to public health and safety must all be considered.

Provisions must be made for monitoring the prospective operations to ensure compliance with development regulations, and all alterations of the plan must be approved by the Supervisor. All data required to justify the plan of operations must be supplied to the Supervisor. Before approving a plan of operations, the Supervisor must consult with appropriate state agencies.[18]

Well Drilling

All well drilling, alterations and abandonment methods, including well spacing programs, must be approved by the Supervisor.[18] Detailed well records must be maintained and held accessible to the Supervisor. Within 30 days after well completion, copies of the records must be transmitted to the Supervisor.[19]

Pollution Control

Lessees must conform to all federal, state and local standards for pollution control, including air, land, water, and noise pollution. The Supervisor may establish additional or more stringent standards.[20]

Disposal of waste effluents is subject to state and federal standards; plans for disposal must be approved by the Supervisor. Surface pits or sumps are not categorically forbidden, but in no event may their contents be allowed 1) to contaminate streams, artificial canals or waterways, groundwaters, lakes or rivers; 2) to adversely affect the environment, persons, plants, fish, wildlife or their habitats; or 3) to damage the aesthetic values of the property or adjacent properties. When abandoned, surface pits must be filled and the surface restored to a near-natural state, as prescribed by the Supervisor.[21] In general, land reclamation is required of all geothermal operations.[22]

Offset Drilling

When production from adjacent lands causes drainage of geothermal resources from federal leases, the lessee must either 1) obtain compensation payments from those benefiting; 2) protect the leased lands by counter-drainage through production wells along the boundary; or 3) pay compensatory royalties to the federal government as approved by the Supervisor.[23] This obligation of protection is extended to all lands under unit agreements which include federal lands.[24]

Royalties

Contracts for the sale of geothermal resources must be filed with the Supervisor within 30 days of their effective date. Geothermal royalties are due during the month subsequent to production. The royalty value of production is "the reasonable value of the energy and the byproducts attributable to the lease as determined by the supervisor."

Several factors are to be considered when assigning value:

a) The highest price paid for a majority of the production of like quality in the same field or area;
b) The total consideration accruing to the lessee from any disposition of the geothermal production;
c) The value of the geothermal production used by the lessee;
d) The value and cost of alternate available energy sources and byproducts;
e) The cost of exploration and production, excluding taxes;
f) The economic value of the resource in terms of its ultimate utilization;
g) Production agreements between producer and purchaser; and
h) Any other matters which the Supervisor may consider relevant.

Under no circumstances may the reasonable value be less than the sum of 1) the total consideration accruing to the lessee under contracts for the sale of geothermal resources, and 2) the value of any endproduct attributable to geothermal resources not sold, but used directly: for example, in manufacturing or power production.[25]

Demineralized water is not subject to royalties if it is used "in plant operation for cooling or in the generation of electric energy or otherwise."[26]

Unit Agreements

The Secretary of the Interior, or his duly authorized representative, must approve a unit agreement which involves a federal geothermal lessee. Such an agreement will not be approved unless the parties involved hold sufficient interests in the area to give effective control of operations therein. This means only that the working interests in the area, as opposed to royalty or other simple participatory interests, must be parties to the agreement.[27]

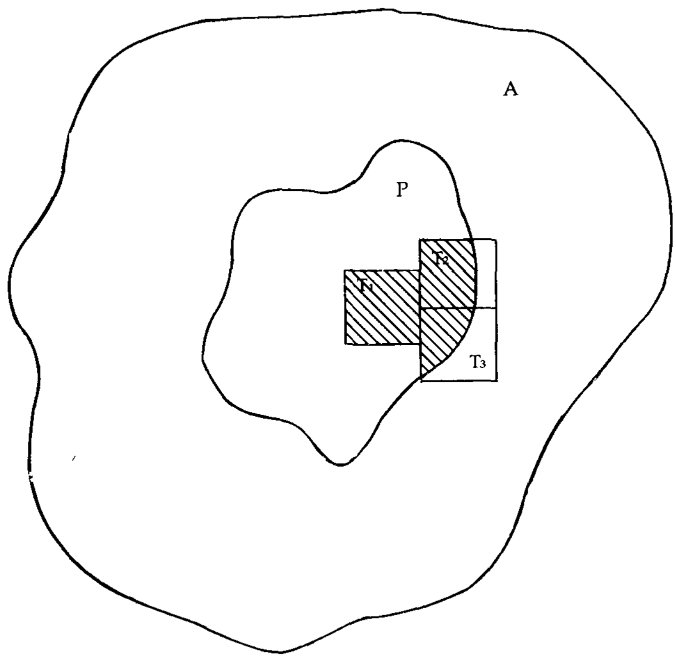
The Director of Geological Survey may require unit operation by federal lessees if necessary for the conservation of natural resources, including the geothermal resources.[28] Where non-federal lands are committed to a unit agreement, any necessary approval by state agencies should be obtained before submission of the unit plan to the Supervisor.[29]

A standard form for unit agreements appears as Section 271.12 of the regulations. Departures from this form proposed in a unit agreement must be reviewed for approval. Where non-federal lands are involved, state law normally applicable to those lands may be incorporated into the unit agreement.[30]

Under the standard form, costs and benefits from unit operation are allocated according to the ratio which a unitized tract's productive area bears to the entire productive area included in the agreement. In Figure 69, "A" is the geothermal area or field, called the unit area, which appears on the basis of geology to be subject to unit operation. "P" is the currently identified productive zone. "T(i)" are the tracts, or unitized land, committed to the unit agreement. Only that portion of the unitized land (T) which overlies the productive area (P) is used in allocation of costs and benefits. This portion of the unitized land is called the participating area. Production is deemed to be equal for all acreage in the participating area.[31]

The identified productive zone may change as knowledge is gained through exploratory and development drilling. These changes will be reflected in the allocation of costs and benefits. If, on the other hand, a productive zone shrinks *through depletion*, participation by the separate tracts in costs and benefits remains unchanged.[32]

The standard form also specifies a significant drilling requirement. The unit operator must initiate a continuous drilling program, allowing no more than six months to elapse between completion of one well and the beginning of the next. This program must be maintained until a well is completed capable of producing geothermal resources in paying quantities, or until the unitized land is reasonably proven to be incapable of commercial production.[33] It may be recalled here that acreage com-



A = Unit Area
P = Productive Zone
T(i) = Unitized Land Tracts
Shaded Portion = Participating Area

Fig. 69. Unitization schema for federal lands

mitted to cooperative plans is exempted when calculating total leaseholdings in a state.[34] To the extent that the drilling requirement is maintained, a certain price is paid for the acreage exemption.

Reports

Assorted reports must be filed with the Supervisor, either periodically or in case of emergency. Geologic and geophysical interpretations, maps, and data required in these reports will not be available for public inspection without the consent of the lessee so long as the lease remains in effect.[35] Below is a list of such reports:[36]

a) If any significant effect on the environment is created by the lessee's operations, the Supervisor must be notified within 24 hours and a written report filed within 30 days.[37] If industrial accidents occur, they must also be reported within 24 hours and a written account filed within 15 days.[38]
b) Log and well history (within 30 days of well completion)
c) Monthly report of operations
d) Monthly report of sales and royalties
e) Annual report of compliance with environmental protection requirements
f) Annual report of expenditures for diligent exploration operations

Geothermal Resources Operational Orders

To effectively regulate geothermal development, the Supervisor may issue GRO orders extending or particularizing the standards for methods of development. GRO orders numbered 1 through 4 have been issued and address, respectively: exploratory operations; drilling, completion and spacing of geothermal wells; plugging and abandonment of wells; and general environmental protection requirements. Before issuing any GRO orders or allowing variances from existing standards, the Supervisor must consult with appropriate state agencies.[39]

Notes

1) 43 CFR 3200.0-5j and 1
2) 43 CFR 3210.1 and 3210.2-2
3) 43 CFR 3209.0-5d; GRO Order No.1
4) 43 CFR 3209.0-5a
5) 43 CFR 3200.0-6
6) 43 CFR 3203.1-3
7) 43 CFR 3200.0-5
8) 43 CFR 3203.1-4a
9) 43 CFR 3203.5
10) Geothermal Steam Act, P.L. 91-581, Section 9
11) 43 CFR 3242.1
12) 43 CFR 3242.2-2
13) 43 CFR 3204.1c
14) 30 CFR Group 270-271
15) 30 CFR 270.2j
16) 30 CFR 207.34
17) 30 CFR 270.11
18) 30 CFR 270.14,15,35,38,45,71,72
19) 30 CFR 270.37,73
20) 30 CFR 270.41; GRO Order No.4
21) 30 CFR 270.44
22) GRO Order No.4
23) 43 CFR 3204.5; 30 CFR 270.33
24) 30 CFR 270.12, Article 10.4
25) 30 CFR 270.42,50,62
26) 43 CFR 3205.3-6
27) 30 CFR 271.8
28) Geothermal Steam Act, P.L. 91-581, Section 18
29) 30 CFR 271.5
30) Ibid.
31) 30 CFR 271.2; 271.12, Article 13
32) 30 CFR 271.12, Article 12.5
33) 30 CFR 271.12, Article 11.5
34) Geothermal Steam Act, P.L. 91-581, Section 18
35) 30 CFR 270.79
36) 30 CFR 270.73 to 270.77
37) 30 CFR 270.30c
38) 30 CFR 270.46
39) 30 CFR 270.11

Appendix 3
Federal Geothermal Lease Summary

Noncompetitive Geothermal Leasing
Summary Status Report

As of: August 31, 1975

	APPLICATIONS							LEASES					
	Filed			Withdrawn	Rejected	Awaiting 1/ Action	Refused by Applicant	Issued			Acres		
State	BLM	FS	Subtotal					BLM	FS	Subtotal	BLM	FS	Subtotal
Alaska	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona	23	1	24	0	5	7	8	3	1	4	4,588	1,920	6,508
California	504	364	868	254	158	454	1	1	0	1	1,280	0	1,280
Colorado	74	67*	141	11	14	104	0	12	0	12	13,421	0	13,421
Idaho	415	235*	650	99	128	367	15	41	0	41	66,732	0	66,732
Montana	33	55*	88	18	24	46	0	0	0	0	0	0	0
Nevada	1,072	13	1,085	371	219	283	31	179	2	181	333,470	2,449	335,919
New Mexico	469	40	509	178	19	264	0	48	0	48	106,130	0	106,130
Oregon	581	280	861	101	256	499	0	5	0	5	5,774	0	5,774
Utah	321	77	398	55	126	153	0	64	0	64	108,524	0	108,524
Washington	0	267	267	38	46	183	0	0	0	0	0	0	0
Wyoming	1	18	19	0	1	18	0	0	0	0	0	0	0
Eastern States	0	12	12	0	1	11	0	0	0	0	0	0	0
Totals	3,493	1,429	4,922	1,125	997	2,389	55	353	3	356	639,919	4,369	644,288

1/ Applications pending for following reasons:

* Applications involve both BLM and FS lands.

Number		Number	
50	Awaiting KGRA report (no overlaps)	861	Pending EAR (BLM only)
121	Suspended for 50% overlap	1,009	Consent of other agencies
29	Pre-lease plan of development	60	Lease forwarded for signature
		259	Processing (BLM)

Geothermal Competitive Lease Sale Summary

As of October 1, 1975

Lease Sale Date and KGRA	Units Offered		Units Bid On		Units Accepted		Leases Issued (No.)	Acreage Under Lease	Total of Accepted High Bids	Highest Per Acre Bid	Average Price Per Acre	High Bidder(s)	No. of Bids Received
	No.	Acreage	No.	Acreage	No.	Acreage							
1/22/74 Geysers, Calif.	12	8,755	12	8,755	10	7,969	10	7,969	$5,045,247	$1,367.52	$ 633.10	Shell Oil Co. Thermogenics, Inc. Union Oil Co. Signal Oil Co. Occidental Pet.	42
1/22/74 East Mesa, Calif.	14	30,169	5	9,210	5	9,210	5	9,210	653,133	169.79	70.91	Magma Power Co. Republic Geothermal, Inc.	5
1/22/74 Mono-Long Valley, Calif.	7	13,715	3	5,483	3	5,483	3	5,483	632,818	290.90	115.41	Chevron Oil Co. Getty Oil Co. Republic Geothermal, Inc.	10
5/29/74 Geysers, Calif. (Reoffered)	2	786	2	786	2	786	2	786	2,275,000	3,282.74	2,894.40	Natomas Co. Occidental Pet.	8
6/4/74 East Mesa, Calif. (Reoffered)	9	20,959	1	2,560	1	2,560	1	2,560	8,371	3.27	3.27	Republic Geothermal, Inc.	1
6/27/74 Vale, Ore.	1	1,347	1	1,347	1	1,347	1	1,347	13,831	10.26	10.26	Republic Geothermal, Inc.	4
7/30/74 Roosevelt Hot Springs, Utah	12	23,392	12	23,392	12	23,392	12	23,392	877,189	128.03	37.49	Union Oil Co. Phillips Pet. Co. Getty Oil Co.	29

As of October 1, 1975

Lease Sale Date and KGRA	Units Offered		Units Bid On		Units Accepted		Leases Issued (No.)	Acreage Under Lease	Total of Accepted High Bids	Highest Per Acre Bid	Average Price Per Acre	High Bidder(s)	No. of Bids Received
	No.	Acreage	No.	Acreage	No.	Acreage							
9/11/74 Brady-Hazen, Nevada	8	12,608	5	6,735	4	4,174	2	4,174	29,109	10.15	6.97	Geothermal Resources, Int'l Magma Power Co. Southern Union Production Co.	6
12/18/74 Beowawe, Nev.	8	16,532	5	11,830	5	11,830	5	11,830	671,257	203.77	56.74	Chevron Oil Co. Getty Oil Co.	12
12/18/74 Hot Springs Point, Nev.	3	5,341	2	4,701	2	4,701	2	4,701	240,894	53.84	51.24	Chevron Oil Co.	4
2/18/74 Brady-Hazen, Nev.	4	8,274	2	5,074	2	5,074	2	5,074	88,912	20.00	17.52	Natomas Co.	3
1/28/75 Clifton, Ariz.	1	780	0	0	0	0	0	0	0	-	-	-	0
3/5/75 Cove-Fort-Sulphurdale, Utah	10	21,059	9	19,409	9	19,409	9	19,409	2,676,123	361.87	137.88	American Geothermal Energy, Inc. Union Oil Co.	11
4/8/75 Fly Ranch, Nev.	7	14,479	4	8,751	4	8,751	4	8,751	41,298	7.77	4.71	Natomas Co. Sun Oil Co. Calvert Drilling Co.	5

As of October 1, 1975

Lease Sale Date and KGRA	Units Offered No.	Units Offered Acreage	Units Bid On No.	Units Bid On Acreage	Units Accepted No.	Units Accepted Acreage	Leases Issued (No.)	Acreage Under Lease	Total of Accepted High Bids	Highest Per Acre Bid	Average Price Per Acre	High Bidder(s)	No. of Bids Received
5/15/75 Kilbourne Hole, New Mexico	12	24,278	9	18,477	9	18,477	9	18,477	$ 359,683	$ 31.26	19.47	Anadarko Production Co.	12
5/20/75 Alamosa County, Mineral Springs Poncha and Valley View, Colorado	8	11,271	3	5,036	3	5,036	3	5,036	13,577	3.17	2.70	Phillips Pet. Co. Anschutz Corp.	3
5/22/75 Mickey Hot Springs, Ore.	14	30,348	6	14,999	3	7,520	3	7,520	44,213	10.25	5.88	Al-Aquitane Exploration LTD. Phillips Pet. Co. Getty Oil Co.	15
5/29/75 Alvord Hot Springs, Ore.	14	26,938	6	12,643	6	12,643	1	2,561	90,714	17.90	7.18	Republic Geo-thermal, Inc. Chevron Oil Co.	8
6/5/75 Borax Lake, Hot Springs, Oregon	16	35,605	8	17,809	5	11,019	5	11,019	44,678	29.50	4.05	MAPCO, Inc. (Tulsa) Getty Oil Co. Southern Union Production Co. Union Oil Co. of California	21

As of October 1, 1975

Lease Sale Date and KGRA	Units Offered No.	Units Offered Acreage	Units Bid On No.	Units Bid On Acreage	Units Accepted No.	Units Accepted Acreage	Leases Issued (No.)	Acreage Under Lease	Total of Accepted High Bids	Highest Per Acre Bid	Average Price Per Acre	High Bidder(s)	No. of Bids Received
6/12/75 Thermo, Lund, Monroe-Joseph, Roosevelt (Reoffered) and Cove Fort-Sulphurdale (Reoffered), Utah	18	30,368	5	6,762	5	6,762	5	6,762	29,495	15.12	4.36	Chevron Oil Co. Thermex Co. Western Geo-thermal, Inc. Gary W. Seltzer	6
6/19/75 Mountain Home - Bruneau, Idaho	5	7,676	2	2,600	2	2,600	2	2,600	5,538	2.13	2.13	Anschutz Corp.	2
6/23/75 Lake City-Surprise Valley, Calif.	16	34,591	5	10,584	5	10,584	5	10,584	134,533	21.53	12.71	Getty Oil Co. Dow Chemical Co. Southern Union Production Co.	6
6/26/75 Stillwater-Soda Lake, Nevada	21	47,157	6	13,259	6	13,259	6	13,259	241,711	45.12	18.23	Phillips Pet. Co. Chevron Oil Co. Union Oil Co. of California Phillips Pet. Co. & Chevron Oil Co. (Joint Bid)	7

As of October 1, 1975

Lease Sale Date and KGRA	Units Offered No.	Units Offered Acreage	Units Bid On No.	Units Bid On Acreage	Units Accepted No.	Units Accepted Acreage	Leases Issued (No.)	Acreage Under Lease	Total of Accepted High Bids	Highest Per Acre Bid	Average Price Per Acre	High Bidder(s)	No. of Bids Received
6/31/75 Crump Geysers, Oregon	18	35,974	4	9,462	4	9,462	4	9,462	37,016	5.12	3.91	Chevron Oil Co.	4
9/23/75 Steamboat Springs, Wabuska and Fly Ranch, Nevada	7	12,916	4	7,188	4	7,188	0	0	109,152	32.31	15.19	Phillips Pet. Co. and Gulf Oil Co. (Joint Bid), Southern Union Production Co.	6
9/25/75 Vale Hot Springs, Oregon	6	12,574	3	7,046	3	7,046	0	0	80,177	16.16	11.38	Union Oil Co., Geothermal Resources International	4
Totals	253	487,892	124	233,898	115	216,282	101	191,966	$14,443,669	NA	66.78	NA	234

Tables of federal competitive and noncompetitive geothermal lease data reproduced from U.S. Bureau of Land Management, "Geothermal Leasing Summary," October 1975.

Appendix 4
Federal Geothermal Steam Act

Public Law 91-581
91st Congress, S. 368
December 24, 1970

An Act

To authorize the Secretary of the Interior to make disposition of geothermal steam and associated geothermal resources, and for other purposes.

Geothermal Steam Act of 1970. Definitions.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Geothermal Steam Act of 1970".

SEC. 2. As used in this Act, the term—

(a) "Secretary" means the Secretary of the Interior;

(b) "geothermal lease" means a lease issued under authority of this Act;

(c) "geothermal steam and associated geothermal resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them;

(d) "byproduct" means any mineral or minerals (exclusive of oil, hydrocarbon gas, and helium) which are found in solution or in association with geothermal steam and which have a value of less than 75 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves;

(e) "known geothermal resources area" means an area in which the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary, engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose.

Leases.

SEC. 3. Subject to the provisions of section 15 of this Act, the Secretary of the Interior may issue leases for the development and utilization of geothermal steam and associated geothermal resources (1) in lands administered by him, including public, withdrawn, and acquired lands, (2) in any national forest or other lands administered by the Department of Agriculture through the Forest Service, including public, withdrawn, and acquired lands, and (3) in lands which have been conveyed by the United States subject to a reservation to the United States of the geothermal steam and associated geothermal resources therein.

Bids.

SEC. 4. If lands to be leased under this Act are within any known geothermal resources area, they shall be leased to the highest responsible qualified bidder by competitive bidding under regulations formulated by the Secretary. If the lands to be leased are not within any known geothermal resources area, the qualified person first making application for the lease shall be entitled to a lease of such lands without competitive bidding. Notwithstanding the foregoing, at any time within one hundred and eighty days following the effective date of this Act:

Conversion.

(a) with respect to all lands which were on September 7, 1965, subject to valid leases or permits issued under the Mineral Leasing Act of February 25, 1920, as amended (30 U.S.C. 181 et seq.), or under the Mineral Leasing Act of Acquired Lands, as amended (30 U.S.C. 351, 358), or to existing mining claims located on or prior to September 7, 1965, the lessees or permittees or claimants or their successors in interest who are qualified to hold geothermal leases shall have the right to convert such leases or permits or claims to geothermal leases covering the same lands;

41 Stat. 437.
61 Stat. 913.

(b) where there are conflicting claims, leases, or permits therefor embracing the same land, the person who first was issued a lease or permit, or who first recorded the mining claim shall be entitled to first consideration;

(c) with respect to all lands which were on September 7, 1965, the subject of applications for leases or permits under the above Acts, the applicants may convert their applications to applications for geothermal leases having priorities dating from the time of filing of such applications under such Acts;

Acreage limitation.

(d) no person shall be permitted to convert mineral leases, permits, applications therefor, or mining claims for more than 10,240 acres; and

(e) the conversion of leases, permits, and mining claims and applications for leases and permits shall be accomplished in accordance with regulations prescribed by the Secretary. No right to conversion to a geothermal lease shall accrue to any person under this section unless such person shows to the reasonable satisfaction of the Secretary that substantial expenditures for the exploration, development, or production of geothermal steam have been made by the applicant who is seeking conversion, on the lands for which a lease is sought or on adjoining, adjacent, or nearby Federal or non-Federal lands.

(f) with respect to lands within any known geothermal resources area and which are subject to a right to conversion to a geothermal lease, such lands shall be leased by competitive bidding: *Provided*, That, the competitive geothermal lease shall be issued to the person owning the right to conversion to a geothermal lease if he makes payment of an amount equal to the highest bona fide bid for the competitive geothermal lease, plus the rental for the first year, within thirty days after he receives written notice from the Secretary of the amount of the highest bid.

Lease provisions. Royalties.

SEC. 5. Geothermal leases shall provide for—

(a) a royalty of not less than 10 per centum or more than 15 per centum of the amount or value of steam, or any other form of heat or energy derived from production under the lease and sold or utilized by the lessee or reasonably susceptible to sale or utilization by the lessee;

(b) a royalty of not more than 5 per centum of the value of any byproduct derived from production under the lease and sold or utilized or reasonably susceptible of sale or utilization by the lessee, except that as to any byproduct which is a mineral named in section 1 of the Mineral Leasing Act of February 25, 1920, as amended (30 U.S.C. 181), the rate of royalty for such mineral shall be the same as that provided in that Act and the maximum rate of royalty for such mineral shall not exceed the maximum royalty applicable under that Act;

41 Stat. 437.

Rent.

(c) payment in advance of an annual rental of not less than $1 per acre or fraction thereof for each year of the lease. If there is no well on the leased lands capable of producing geothermal resources in commercial quantities, the failure to pay rental on or before the anniversary date shall terminate the lease by operation of law: *Provided, however*, That whenever the Secretary discovers that the rental payment due under a lease is paid timely but the amount of the payment is deficient because of an error or other reason and the deficiency is nominal, as determined by the Secretary pursuant to regulations prescribed by him, he shall notify the lessee of the deficiency and such lease shall not automatically terminate unless

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the lessee fails to pay the deficiency within the period prescribed in the notice: *Provided further*, That, where any lease has been terminated automatically by operation of law under this section for failure to pay rental timely and it is shown to the satisfaction of the Secretary of the Interior that the failure to pay timely the lease rental was justifiable or not due to a lack of reasonable diligence, he in his judgment may reinstate the lease if—

(1) a petition for reinstatement, together with the required rental, is filed with the Secretary of the Interior; and

(2) no valid lease has been issued affecting any of the lands in the terminated lease prior to the filing of the petition for reinstatement; and

(d) a minimum royalty of $2 per acre or fraction thereof in lieu of rental payable at the expiration of each lease year for each producing lease, commencing with the lease year beginning on or after the commencement of production in commercial quantities. For the purpose of determining royalties hereunder the value of any geothermal steam and byproduct used by the lessee and not sold and reasonably susceptible of sale shall be determined by the Secretary, who shall take into consideration the cost of exploration and production and the economic value of the resource in terms of its ultimate utilization.

Term. SEC. 6. (a) Geothermal leases shall be for a primary term of ten years. If geothermal steam is produced or utilized in commercial quantities within this term, such lease shall continue for so long thereafter as geothermal steam is produced or utilized in commercial quantities, but such continuation shall not exceed an additional forty years.

Limitation. Renewal. (b) If, at the end of such forty years, steam is produced or utilized in commercial quantities and the lands are not needed for other purposes, the lessee shall have a preferential right to a renewal of such lease for a second forty-year term in accordance with such terms and conditions as the Secretary deems appropriate.

Extension. (c) Any lease for land on which, or for which under an approved cooperative or unit plan of development or operation, actual drilling operations were commenced prior to the end of its primary term and are being diligently prosecuted at that time shall be extended for five years and so long thereafter, but not more than thirty-five years, as geothermal steam is produced or utilized in commercial quantities. If, at the end of such extended term, steam is being produced or utilized in commercial quantities and the lands are not needed for other purposes, the lessee shall have a preferential right to a renewal of such lease for a second term in accordance with such terms and conditions as the Secretary deems appropriate.

(d) For purposes of subsection (a) of this section, production or utilization of geothermal steam in commercial quantities shall be deemed to include the completion of one or more wells producing or capable of producing geothermal steam in commercial quantities and a bona fide sale of such geothermal steam for delivery to or utilization by a facility or facilities not yet installed but scheduled for installation not later than fifteen years from the date of commencement of the primary term of the lease.

(e) Leases which have extended by reasons of production, or which have produced geothermal steam, and have been determined by the Secretary to be incapable of further commercial production and utilization of geothermal steam may be further extended for a period of not more than five years from the date of such determination but only for so long as one or more valuable byproducts are produced in commercial quantities. If such byproducts are leasable under the Mineral Leasing Act of February 25, 1920, as amended (30 U.S.C. 181, et seq.), or under the Mineral Leasing Act for Acquired Lands (30 U.S.C.

41 Stat. 437.

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61 Stat. 913. 351-358), and the leasehold is primarily valuable for the production thereof, the lessee shall be entitled to convert his geothermal lease to a mineral lease under, and subject to all the terms and conditions of, such appropriate Act upon application at any time before expiration of the lease extension by reason of byproduct production. The lessee shall be entitled to locate under the mining laws all minerals which are not leasable and which would constitute a byproduct if commercial production or utilization of geothermal steam continued. The lessee in order to acquire the rights herein granted him shall complete the location of mineral claims within ninety days after the termination of the lease for geothermal steam. Any such converted lease or the surface of any mining claim located for geothermal byproducts mineral affecting lands withdrawn or acquired in aid of a function of a Federal department or agency, including the Department of the Interior, shall be subject to such additional terms and conditions as may be prescribed by such department or agency with respect to the additional operations or effects resulting from such conversion upon adequate utilization of the lands for the purpose for which they are administered.

(f) Minerals locatable under the mining laws of the United States in lands subject to a geothermal lease issued under the provisions of this Act which are not associated with the geothermal steam and associated geothermal resources of such lands as defined in section 2(c) herein shall be locatable under said mining laws in accordance with the principles of the Multiple Mineral Development Act (68 Stat. 708; found in 30 U.S.C. 521 et seq.).

Leases, acreage. SEC. 7. A geothermal lease shall embrace a reasonably compact area of not more than two thousand five hundred and sixty acres, except where a departure therefrom is occasioned by an irregular subdivision

Limitation. or subdivisions. No person, association, or corporation, except as otherwise provided in this Act, shall take, hold, own, or control at one time, whether acquired directly from the Secretary under this Act or otherwise, any direct or indirect interest in Federal geothermal leases in any one State exceeding twenty thousand four hundred and eighty acres, including leases acquired under the provisions of section 4 of this Act.

Increase. At any time after fifteen years from the effective date of this Act the Secretary, after public hearings, may increase this maximum holding in any one State by regulation, not to exceed fifty-one thousand two hundred acres.

Readjustment. SEC. 8. (a) The Secretary may readjust the terms and conditions, except as otherwise provided herein, of any geothermal lease issued under this Act at not less than ten-year intervals beginning ten years after the date the geothermal steam is produced, as determined by the Secretary. Each geothermal lease issued under this Act shall provide for such readjustment. The Secretary shall give notice of any proposed readjustment of terms and conditions, and, unless the lessee files with the Secretary objection to the proposed terms or relinquishes the lease within thirty days after receipt of such notice, the lessee shall conclusively be deemed to have agreed with such terms and conditions. If the lessee files objections, and no agreement can be reached between the Secretary and the lessee within a period of not less than sixty days, the lease may be terminated by either party. Notice.

(b) The Secretary may readjust the rentals and royalties of any geothermal lease issued under this Act at not less than twenty-year intervals beginning thirty-five years after the date geothermal steam is produced, as determined by the Secretary. In the event of any such readjustment neither the rental nor royalty may be increased by more than 50 per centum over the rental or royalty paid during the preceding period, and in no event shall the royalty payable exceed 22½ per centum. Each geothermal lease issue under this Act shall provide

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for such readjustment. The Secretary shall give notice of any proposed readjustment of rentals and royalties, and, unless the lessee files with the Secretary objection to the proposed rentals and royalties or relinquishes the lease within thirty days after receipt of such notice, the lessee shall conclusively be deemed to have agreed with such terms and conditions. If the lessee files objections, and no agreement can be reached between the Secretary and the lessee within a period of not less than sixty days, the lease may be terminated by either party. Notice.

(c) Any readjustment of the terms and conditions as to use, protection, or restoration of the surface of any lease of lands withdrawn or acquired in aid of a function of a Federal department or agency other than the Department of the Interior may be made only upon notice to, and with the approval of, such department or agency.

SEC. 9. If the production, use, or conversion of geothermal steam is susceptible of producing a valuable byproduct or byproducts, including commercially demineralized water for beneficial uses in accordance with applicable State water laws, the Secretary shall require substantial beneficial production or use thereof unless, in individual circumstances he modifies or waives this requirement in the interest of conservation of natural resources or for other reasons satisfactory to him. However, the production or use of such byproducts shall be subject to the rights of the holders of preexisting leases, claims. or permits covering the same land or the same minerals, if any. Byproducts.

SEC. 10. The holder of any geothermal lease at any time may make and file in the appropriate land office a written relinquishment of all rights under such lease or of any legal subdivision of the area covered by such lease. Such relinquishment shall be effective as of the date of its filing. Thereupon the lessee shall be released of all obligations thereafter accruing under said lease with respect to the lands relinquished, but no such relinquishment shall release such lessee, or his surety or bond, from any liability for breach of any obligation of the lease, other than an obligation to drill, accrued at the date of the relinquishment, or from the continued obligation, in accordance with the applicable lease terms and regulations, (1) to make payment of all accrued rentals and royalties, (2) to place all wells on the relinquished lands in condition for suspension or abandonment, and (3) to protect or restore substantially the surface and surface resources. Relinquishment.

SEC. 11. The Secretary, upon application by the lessee, may authorize the lessee to suspend operations and production on a producing lease and he may, on his own motion, in the interest of conservation suspend operations on any lease but in either case he may extend the lease term for the period of any suspension, and he may waive, suspend, or reduce the rental or royalty required in such lease. Suspension.

SEC. 12. Leases may be terminated by the Secretary for any violation of the regulations or lease terms after thirty days notice provided that such violation is not corrected within the notice period, or in the event the violation is such that it cannot be corrected within the notice period then provided that lessee has not commenced in good faith within said notice period to correct such violation and thereafter to proceed diligently to correct such violation. Lessee shall be entitled to a hearing on the matter of such claimed violation or proposed termination of lease if request for a hearing is made to the Secretary within the thirty-day period after notice. The period for correction of violation or commencement to correct such violation of regulations or of lease terms, as aforesaid, shall be extended to thirty days after the Secretary's decision after such hearing if the Secretary shall find that a violation exists. Leases, termination. Notice.

SEC. 13. The Secretary may waive, suspend, or reduce the rental or royalty for any lease or portion thereof in the interests of conservation and to encourage the greatest ultimate recovery of geothermal

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resources, if he determines that this is necessary to promote development or that the lease cannot be successfully operated under the lease terms.

SEC. 14. Subject to the other provisions of this Act, a lessee shall be entitled to use so much of the surface of the land covered by his geothermal lease as may be found by the Secretary to be necessary for the production, utilization, and conservation of geothermal resources. Surface land, use.

SEC. 15. (a) Geothermal leases for lands withdrawn or acquired in aid of functions of the Department of the Interior may be issued only under such terms and conditions as the Secretary may prescribe to insure adequate utilization of the lands for the purposes for which they were withdrawn or acquired.

(b) Geothermal leases for lands withdrawn or acquired in aid of functions of the Department of Agriculture may be issued only with the consent of, and subject to such terms and conditions as may be prescribed by, the head of that Department to insure adequate utilization of the lands for the purposes for which they were withdrawn or acquired. Geothermal leases for lands to which section 24 of the Federal Power Act, as amended (16 U.S.C. 818), is applicable, may be issued only with the consent of, and subject to, such terms and conditions as the Federal Power Commission may prescribe to insure adequate utilization of such lands for power and related purposes. 41 Stat. 1075; 62 Stat. 275.

(c) Geothermal leases under this Act shall not be issued for lands administered in accordance with (1) the Act of August 25, 1916 (39 Stat. 535), as amended or supplemented, (2) for lands within a national recreation area, (3) for lands in a fish hatchery administered by the Secretary, wildlife refuge, wildlife range, game range, wildlife man- 16 USC 1.

agement area, waterfowl production area, or for lands acquired or reserved for the protection and conservation of fish and wildlife that are threatened with extinction, (4) for tribally or individually owned Indian trust or restricted lands, within or without the boundaries of Indian reservations.

Lessees, citizenship requirement.

SEC. 16. Leases under this Act may be issued only to citizens of the United States, associations of such citizens, corporations organized under the laws of the United States or of any State or the District of Columbia, or governmental units, including, without limitation, municipalities.

SEC. 17. Administration of this Act shall be under the principles of multiple use of lands and resources, and geothermal leases shall, insofar as feasible, allow for coexistence of other leases of the same lands for deposits of minerals under the laws applicable to them, for the location and production of claims under the mining laws, and for other uses of the areas covered by them. Operations under such other leases or for such other uses, however, shall not unreasonably interfere with or endanger operations under any lease issued pursuant to this Act, nor shall operations under leases so issued unreasonably interfere with or endanger operations under any lease, license, claim, or permit issued pursuant to the provisions of any other Act.

Cooperative or unit plan.

SEC. 18. For the purpose of properly conserving the natural resources of any geothermal pool, field, or like area, or any part thereof, lessees thereof and their representatives may unite with each other, or jointly or separately with others, in collectively adopting and operating under a cooperative or unit plan of development or operation of such pool, field, or like area, or any part thereof, whenever this is determined and certified by the Secretary to be necessary or advisable in the public interest. The Secretary may in his discretion and with the consent of the holders of leases involved, establish, alter, change, revoke, and make such regulations with reference to such leases in connection with the institution and operation of any such cooperative or unit plan as he may deem necessary or proper to secure reasonable protection of the

84 STAT. 1572

public interest. He may include in geothermal leases a provision requiring the lessee to operate under such a reasonable cooperative or unit plan, and he may prescribe such a plan under which such lessee shall operate, which shall adequately protect the rights of all parties in interest, including the United States. Any such plan may, in the discretion of the Secretary, provide for vesting in the Secretary or any other person, committee, or Federal or State agency designated therein, authority to alter or modify from time to time the rate of prospecting and development and the quantity and rate of production under such plan. All leases operated under any such plan approved or prescribed by the Secretary shall be excepted in determining holdings or control for the purposes of section 7 of this Act.

When separate tracts cannot be independently developed and operated in conformity with an established well-spacing or development program, any lease, or a portion thereof, may be pooled with other lands, whether or not owned by the United States, under a communitization or drilling agreement providing for an apportionment of production or royalties among the separate tracts of land comprising the drilling or spacing unit when determined by the Secretary to be in the public interest, and operations or production pursuant to such an agreement shall be deemed to be operations or production as to each lease committed thereto.

The Secretary is hereby authorized, on such conditions as he may prescribe, to approve operating, drilling, or development contracts made by one or more lessees of geothermal leases, with one or more persons, associations, or corporations whenever, in his discretion, the conservation of natural products or the public convenience or necessity may require or the interests of the United States may be best served thereby. All leases operated under such approved operating, drilling, or development contracts, and interests thereunder, shall be excepted in determining holdings or control under section 7 of this Act.

SEC. 19. Upon request of the Secretary, other Federal departments and agencies shall furnish him with any relevant data then in their possession or knowledge concerning or having bearing upon fair and adequate charges to be made for geothermal steam produced or to be produced for conversion to electric power or other purposes. Data given to any department or agency as confidential under law shall not be furnished in any fashion which identifies or tends to identify the business entity whose activities are the subject of such data or the person or persons who furnished such information.

Moneys.

SEC. 20. All moneys received under this Act from public lands under the jurisdiction of the Secretary shall be disposed of in the same manner as moneys received from the sale of public lands. Moneys received under this Act from other lands shall be disposed of in the same manner as other receipts from such lands.

Publication in Federal Register.

SEC. 21. (a) Within one hundred and twenty days after the effective date of this Act, the Secretary shall cause to be published in the Federal Register a determination of all lands which were included within any known geothermal resources area on the effective date of the Act. He shall likewise publish in the Federal Register from time to time his determination of other known geothermal resources areas specifying in each case the date the lands were included in such area; and

(b) Geothermal resources in lands the surface of which has passed from Federal ownership but in which the minerals have been reserved to the United States shall not be developed or produced except under geothermal leases made pursuant to this Act. If the Secretary of the Interior finds that such development is imminent, or that production from a well heretofore drilled on such lands is imminent, he shall so report to the Attorney General, and the Attorney General is authorized

84 STAT. 1573

and directed to institute an appropriate proceeding in the United States district court of the district in which such lands are located, to quiet the title of the United States in such resources, and if the court determines that the reservation of minerals to the United States in the lands involved included the geothermal resources, to enjoin their production otherwise than under the terms of this Act: *Provided*, That upon an authoritative judicial determination that Federal mineral reservation does not include geothermal steam and associated geothermal resources the duties of the Secretary of the Interior to report and of the Attorney General to institute proceedings, as hereinbefore set forth, shall cease.

SEC. 22. Nothing in this Act shall constitute an express or implied claim or denial on the part of the Federal Government as to its exemption from State water laws.

Waste, prevention.

SEC. 23. (a) All leases under this Act shall be subject to the condition that the lessee will, in conducting his exploration, development, and producing operations, use all reasonable precautions to prevent waste of geothermal steam and associated geothermal resources developed in the lands leased.

(b) Rights to develop and utilize geothermal steam and associated geothermal resources underlying lands owned by the United States may be acquired solely in accordance with the provisions of this Act.

Rules and regulations.

SEC. 24. The Secretary shall prescribe such rules and regulations as he may deem appropriate to carry out the provisions of this Act. Such regulations may include, without limitation, provisions for (a) the prevention of waste, (b) development and conservation of geothermal and other natural resources, (c) the protection of the public interest, (d) assignment, segregation, extension of terms, relinquishment of leases, development contracts, unitization, pooling, and drilling agreements, (e) compensatory royalty agreements, suspension of operations or production, and suspension or reduction of rentals or royalties, (f) the filing of surety bonds to assure compliance with the terms of the lease and to protect surface use and resources, (g) use of the surface by a lessee of the lands embraced in his lease, (h) the maintenance by the lessee of an active development program, and (i) protection of water quality and other environmental qualities.

SEC. 25. As to any land subject to geothermal leasing under section 3 of this Act, all laws which either (a) provide for the disposal of land by patent or other form of conveyance or by grant or by operation of law subject to a reservation of any mineral or (b) prevent or restrict the disposal of such land because of the mineral character of the land, shall hereafter be deemed to embrace geothermal steam and associated geothermal resources as a substance which either must be reserved or must prevent or restrict the disposal of such land, as the case may be. This section shall not be construed to affect grants, patents, or other forms of conveyances made prior to the date of enactment of this Act.

SEC. 26. The first two clauses in section 11 of the Act of August 13, 1954 (68 Stat. 708, 716), are amended to read as follows: 30 USC 530.

"As used in this Act, 'mineral leasing laws' shall mean the Act of February 25, 1920 (41 Stat. 437); the Act of April 17, 1926 (44 Stat. 301); the Act of February 7, 1927 (44 Stat. 1057); Geothermal Steam Act of 1970, and all Acts heretofore or hereafter enacted which are amendatory of or supplementary to any of the foregoing Acts; 'Leasing Act minerals' shall mean all minerals which, upon the effective date of this Act, are provided in the mineral leasing laws to be disposed of thereunder and all geothermal steam and associated geothermal resources which, upon the effective date of the Geothermal Steam Act of 1970, are provided in that Act to be disposed of thereunder;".

30 USC 181.
30 USC 281.

84 STAT. 1574

Certain mineral rights, retention by U. S.

SEC. 27. The United States reserves the ownership of and the right to extract under such rules and regulations as the Secretary may prescribe oil, hydrocarbon gas, and helium from all geothermal steam and associated geothermal resources produced from lands leased under this Act in accordance with presently applicable laws: *Provided*, That whenever the right to extract oil, hydrocarbon gas, and helium from geothermal steam and associated geothermal resources produced from such lands is exercised pursuant to this section, it shall be exercised so as to cause no substantial interference with the production of geothermal steam and associated geothermal resources from such lands.

Approved December 24, 1970.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 91-1544 (Comm. on Interior and Insular Affairs).
SENATE REPORT No. 91-1160 (Comm. on Interior and Insular Affairs).
CONGRESSIONAL RECORD, Vol. 116 (1970):
Sept. 16, Oct. 14, Dec. 4, 10, considered and passed Senate.
Oct. 5, Dec. 9, considered and passed House.

Appendix 5

Federal Geothermal Energy Research, Development, and Demonstration Act

GEOTHERMAL ENERGY RESEARCH, DEVELOPMENT,
AND DEMONSTRATION ACT OF 1974,
Public Law 93-410
93rd Congress, H.R. 14950,
September 3, 1974

An Act

To further the conduct of research, development, and demonstrations in geothermal energy technologies, to establish a Geothermal Energy Coordination and Management Project, to provide for the carrying out of research and development in geothermal energy technology, to carry out a program of demonstrations in technologies for the utilization of geothermal resources, to establish a loan guaranty program for the financing of geothermal energy development, and for other purposes.

Geothermal Energy Research, Development, and Demonstration Act of 1974. 30 USC 1101 note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Geothermal Energy Research, Development, and Demonstration Act of 1974".

FINDINGS

30 USC 1101.

SEC. 2. The Congress hereby finds that—

(1) the Nation is currently suffering a critical shortage of environmentally acceptable forms of energy;

(2) the inadequate organizational structures and levels of funding for energy research have limited the Nation's current and future options for meeting energy needs;

(3) electric energy is a clean and convenient form of energy at the location of its use and is the only practicable form of energy in some modern applications, but the demand for electric energy in every region of the United States is taxing all of the alternative energy sources presently available and is projected to increase; some of the sources available for electric power generation are already in short supply, and the development and use of other sources presently involve undesirable environmental impacts;

(4) the Nation's critical energy problems can be solved only if a national commitment is made to dedicate the necessary financial resources, and enlist the cooperation of the private and public sectors, in developing geothermal resources and other nonconventional sources of energy;

(5) the conventional geothermal resources which are presently being used have limited total potential; but geothermal resources which are different from those presently being used, and which have extremely large energy content, are known to exist;

(6) some geothermal resources contain energy in forms other than heat; examples are methane and extremely high pressures available upon release as kinetic energy;

(7) some geothermal resources contain valuable byproducts such as potable water and mineral compounds which should be processed and recovered as national resources;

88 STAT. 1079
88 STAT. 1080

(8) technologies are not presently available for the development of most of these geothermal resources, but technologies for the generation of electric energy from geothermal resources are potentially economical and environmentally desirable, and the development of geothermal resources offers possibilities of process energy and other nonelectric applications;

(9) much of the known geothermal resources exist on the public lands;

(10) Federal financial assistance is necessary to encourage the extensive exploration, research, and development in geothermal resources which will bring these technologies to the point of commercial application;

(11) the advancement of technology with the cooperation of private industry for the production of useful forms of energy from geothermal resources is important with respect to the Federal responsibility for the general welfare, to facilitate commerce, to encourage productive harmony between man and his environment, and to protect the public interest; and

(12) the Federal Government should encourage and assist private industry through Federal assistance for the development and demonstration of practicable means to produce useful energy from geothermal resources with environmentally acceptable processes.

DEFINITIONS

SEC. 3. For the purposes of this Act— 30 USC 1102.

(1) the term "geothermal resources" means (A) all products of geothermal processes, embracing indigenous steam, hot water, and brines, (B) steam and other gases, hot water and hot brines, resulting from water, gas, or other fluids artificially introduced into geothermal formations, and (C) any byproduct derived from them;

(2) the term "byproduct" means any mineral or minerals which are found in solution or in association with geothermal resources and which have a value of less than 75 percent of the value of the geothermal steam and associated geothermal resources or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves;

(3) "pilot plant" means an experimental unit of small size used for early evaluation and development of new or improved processes and to obtain technical, engineering, and cost data;

(4) "demonstration plant" means a complete facility which produces electricity, heat energy, or useful byproducts for commercial disposal from geothermal resources and which will make a significant contribution to the knowledge of full-size technology, plant operation, and process economics;

(5) the term "Project" means the Geothermal Energy Coordination and Management Project established by section 101(a);

(6) the term "fund" means the Geothermal Resources Development Fund established by section 204(a); and

(7) the term "Chairman" means the Chairman of the Project.

TITLE I—GEOTHERMAL ENERGY COORDINATION AND MANAGEMENT PROJECT

ESTABLISHMENT

SEC. 101. (a) There is hereby established the Geothermal Energy Coordination and Management Project. 30 USC 1121.

(b)(1) The Project shall be composed of six members as follows: Membership.

(A) one appointed by the President; 88 STAT. 1080

(B) an Assistant Director of the National Science Foundation; 88 STAT. 1081

(C) an Assistant Secretary of the Department of the Interior;

(D) an Associate Administrator of the National Aeronautics and Space Administration;

88 STAT. 1081

(E) the General Manager of the Atomic Energy Commission; and

(F) an Assistant Administrator of the Federal Energy Administration.

(2) The President shall designate one member of the Project to serve as *Chairman of the Project.*

Compensation. (3) If the individual appointed under paragraph (1)(A) is an officer or employee of the Federal Government, he shall receive no additional pay on account of his service as a member of the Project. If such individual is not an officer or employee of the Federal Government, he shall be entitled to receive the daily equivalent of the annual rate of basic pay in effect for level IV of the Executive Schedule (5 U.S.C. 5315) for each day (including traveltime) during which he is engaged in the actual performance of duties vested in the Project.

80 Stat. 461; 83 Stat. 863.

(c) The Project shall have overall responsibility for the provision of effective management and coordination with respect to a national geothermal energy research, development, and demonstration program. Such program shall include—

(1) the determination and evaluation of the resource base;

(2) research and development with respect to exploration, extraction, and utilization technologies;

(3) the demonstration of appropriate technologies; and

(4) the loan guaranty program under title II.

(d)(1) The Project shall carry out its responsibilities under this section acting through the following Federal agencies:

(A) the Department of the Interior, the responsibilities of which shall include evaluation and assessment of the resource base, including development of exploration technologies;

(B) the National Aeronautics and Space Administration, the responsibilities of which shall include the provision of contract management capability, evaluation and assessment of the resource base, and the development of technologies pursuant to section 102(b);

(C) the Atomic Energy Commission, the responsibilities of which shall include the development of technologies; and

(D) the National Science Foundation, the responsibilities of which shall include basic and applied research.

(2) Upon request of the Project, the head of any such agency is authorized to detail or assign, on a reimbursable basis or otherwise, any of the personnel of such agency to the Project to assist it in carrying out its responsibilities under this Act.

(e) The Project shall have exclusive authority with respect to the establishment or approval of programs or projects initiated under this Act, except that the agency involved in any particular program or project shall be responsible for the operation and administration of such program or project.

PROGRAM DEFINITION

30 USC 1122. SEC. 102. (a)(1) The Chairman, acting through the Administrator of the National Aeronautics and Space Administration, is authorized and directed to prepare a comprehensive program definition of an integrated effort and commitment for effectively developing geothermal energy resources. Such Administrator, in preparing such comprehensive program definition, is authorized to consult with other Federal agencies and non-Federal entities.

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Transmittal to President and Congress. Interim reports.

(2) The Chairman shall transmit such comprehensive program definition to the President and to each House of the Congress. Interim reports shall be transmitted not later than November 30, 1974, and not later than January 31, 1975. Such comprehensive program definition shall be transmitted as soon as possible thereafter, but in any case not later than August 31, 1975.

Inventory schedule and objectives, transmittal to President and Congress.

(3) As part of the comprehensive program definition required by paragraph (1), the Chairman, acting through the Geological Survey, shall transmit to the President and to each House of the Congress a schedule and objectives for the inventorying of geothermal resources.

(b) The National Aeronautics and Space Administration is authorized to undertake and carry out those programs assigned to it by the Project.

RESOURCE INVENTORY AND ASSESSMENT PROGRAM

30 USC 1123. SEC. 103. (a) The Chairman shall initiate a resource inventory and assessment program with the objective of making regional and national appraisals of all types of geothermal resources, including identification of promising target areas for industrial exploration and development. The specific goals shall include—

(1) the improvement of geophysical, geochemical, geological, and hydrological techniques necessary for locating and evaluating geothermal resources;

(2) the development of better methods for predicting the power potential and longevity of geothermal reservoirs;

(3) the determination and assessment of the nature and power potential of the deeper unexplored parts of high temperature geothermal convection systems; and

(4) the survey and assessment of regional and national geothermal resources of all types.

(b) The Chairman, acting through the Geological Survey and other appropriate agencies, shall—

(1) develop and carry out a general plan for the orderly inventorying of all forms of geothermal resources of the Federal lands and, where consistent with property rights and determined by the Chairman to be in the national interest, of non-Federal lands;

(2) conduct regional surveys, based upon such a general plan, using innovative geological, geophysical, geochemical, and stratagraphic drilling techniques, which will lead to a national inventory of geothermal resources in the United States;

(3) publish and make available maps, reports, and other documents developed from such surveys to encourage and facilitate the commercial development of geothermal resources for beneficial use and consistent with the national interest;

(4) make such recommendations for legislation as may from time to time appear to be necessary to make Federal leasing policy for geothermal resources consistent with known inventories of various resource types, with the current state of technologies for geothermal energy development, and with current evaluations of the environmental impacts of such development; and

(5) participate with appropriate Federal agencies and non-Federal entities in research to develop, improve, and test technologies for the discovery and evaluation of all forms of geothermal resources, and conduct research into the principles controlling the location, occurrence, size, temperature, energy content, producibility, and economic lifetimes of geothermal reservoirs.

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RESEARCH AND DEVELOPMENT

SEC. 104. (a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a research and development program for the purpose of resolving all major technical problems inhibiting the fullest possible commercial utilization of geothermal resources in the United States. The specific goals of such programs shall include— 30 USC 1124.

(1) the development of effective and efficient drilling methods to operate at high temperatures in formations of geothermal interest;

(2) the development of reliable predictive methods and control techniques for the production of geothermal resources from reservoirs;

(3) the exploitation of new concepts for fracturing rock to permit recovery of contained heat reserves;

(4) the improvement of equipment and technology for the extraction of geothermal resources from reservoirs;

(5) the development of improved methods for converting geothermal resources and byproducts to useful forms;

(6) the development of improved methods for controlling emissions and wastes from geothermal utilization facilities, including new monitoring methods to any extent necessary;

(7) the development and evaluation of waste disposal control technologies and the evaluation of surface and subsurface environmental effects of geothermal development;

(8) the improvement of the technical capability to predict environmental impacts resulting from the development of geothermal resources, the preparation of environmental impact statements, and the assuring of compliance with applicable standards and criteria;

(9) the identification of social, legal, and economic problems associated with geothermal development (both locally and regionally) for the purpose of developing policy and providing a framework of policy alternatives for the commercial utilization of geothermal resources;

(10) the provision for an adequate supply of scientists to perform required geothermal research and development activities; and

(11) the establishment of a program to encourage States to establish and maintain geothermal resources clearinghouses, which shall serve to (A) provide geothermal resources developers with information with respect to applicable local, State, and Federal laws, *rules, and regulations,* (B) *coordinate the processing of* permit applications, impact statements, and other information which geothermal resources developers are required to provide, (C) encourage uniformity with respect to local and State laws, rules, and regulations with respect to geothermal resources development, and (D) encourage establishment of land use plans, which would include zoning for geothermal resources development and which would assure that geothermal resources developers will be able to carry out development programs to the production stage.

(b) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall implement a coordinated program of research and development in order to demonstrate the technical means for the extraction and utilization of the resource base, including any byproducts of such base, and in order to

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accomplish the goals established by subsection (a). Research authorized by this Act having potential applications in matters other than geothermal energy may be pursued to the extent that the findings of such research can be published in a form for utilization by others.

DEMONSTRATION

SEC. 105. (a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a program to design and construct geothermal demonstration plants. The specific goals of such program shall include— 30 USC 1125.

(1) the development of economical geothermal resources production systems and components which meet environmental standards;

(2) the design of plants to produce electric power and, where appropriate, the large-scale production and utilization of any useful byproducts;

(3) the involvement of engineers, analysts, technicians, and managers from industry field and powerplant development, which shall lead to the early industrial exploitation of advanced geothermal resources;

(4) the provision for an adequate supply of trained geothermal engineers and technicians;

(5) the provision of experimental test beds for component testing an evaluation by laboratories operated by the Federal Government, industry, or institutions of higher education;

(6) the construction and operation of pilot plants; and

(7) the construction and operation of demonstration plants.

(b) In carrying out his responsibilities under this section, the Chairman, acting through the appropriate Federal agencies, and in cooperation with non-Federal entities, may provide for the establishment of one or more demonstration projects utilizing each geothermal resource base involved, which shall include, as *appropriate, all of the* exploration, siting, drilling, pilot plant construction and operation, demonstration plant construction and operation, and other facilities and activities which may be necessary for the generation of electric energy and the utilization of geothermal resource byproducts.

Cooperative agreements.

(c) The Chairman, acting through the appropriate Federal agencies, is authorized to investigate and enter into agreements for the cooperative development of facilities to demonstrate the production of energy from geothermal resources. The responsible Federal agency may consider—

(1) cooperative agreements with utilities and non-Federal governmental entities for construction of facilities to produce energy for commercial disposition; and

(2) cooperative agreements with other Federal agencies for the construction and operation of facilities to produce energy for direct Federal consumption.

(d) The responsible Federal agency is authorized to investigate the feasibility of, construct, and operate, demonstration projects without entering into cooperative agreements with respect to such projects, if the Chairman finds that—

(1) the nature of the resource, the geographical location, the scale and engineering design of the facilities, the techniques of production, or any other significant factor of the proposal offers opportunities to make important contributions to the general

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knowledge of geothermal resources, the techniques of its development, or public confidence in the technology; and

(2) there is no opportunity for cooperative agreements with any utility or non-Federal governmental entity willing and able to cooperate in the demonstration project under subsection (c) (1), and there is no opportunity for cooperative agreements with other Federal agencies under subsection (c)(2).

(e) Before favorably considering proposals under subsection (c), the responsible Federal agency must find that—

(1) the nature of the resource, the geographical location, the scale and engineering design of the facilities, the techniques of production, or any other significant factor of the proposal offers opportunities to make important contributions to the general knowledge of geothermal resources, the techniques of its development, or public confidence in the technology;

(2) the development of the practical benefits as set forth in paragraph (1) are unlikely to be accomplished without such cooperative development; and

(3) where non-Federal participants are involved, the proposal is not eligible for adequate Federal assistance under the loan guaranty provisions of title II of this Act.

(f) If the estimate of the Federal investment with respect to construction and operation costs of any demonstration project proposed to be established under this section exceeds $10,000,000, no amount may be appropriated for such project except as specifically authorized by legislation hereafter enacted by the Congress.

Federal property interests, disposal.

(g)(1) At the conclusion of the program under this section or as soon thereafter as may be practicable, the responsible Federal agencies shall, by sale, lease, or otherwise, dispose of all Federal-property interests which they have acquired pursuant to this section (including mineral rights) in accordance with existing law and the terms of the cooperative agreements involved.

Project by-products, disposal.

(2) The agency involved shall, under appropriate agreements or other arrangements, provide for the disposition of geothermal resource byproducts of the project administered by such agency.

SCIENTIFIC AND TECHNICAL EDUCATION

30 USC 1126.

SEC. 106. (a) It is the policy of the Congress to encourage the development and maintenance of programs through which there may be provided the necessary trained personnel to perform required geothermal research, development, and demonstration activities under sections 103, 104, and 105.

(b) The National Science Foundation is authorized to support programs of education in the sciences and engineering to carry out the policy of subsection (a). Such support may include fellowships, traineeships, technical training programs, technologist training programs, and summer institute programs.

(c) The National Science Foundation is authorized and directed to coordinate its actions, to the maximum extent practicable, with the Project or any permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States, in determining the optimal selection of programs of education to carry out the policy of subsection (a).

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(d) The National Science Foundation is authorized to encourage, to the maximum extent practicable international participation and cooperation in the development and maintenance of programs of education to carrying out the policy of subsection (a).

TITLE II—LOAN GUARANTIES

ESTABLISHMENT OF LOAN GUARANTY PROGRAM

30 USC 1141.

SEC. 201. (a) It is the policy of the Congress to encourage and assist in the commercial development of practicable means to produce useful energy from geothermal resources with environmentally acceptable processes. Accordingly, it is the policy of the Congress to facilitate such commercial development by authorizing the Chairman of the Project to designate an appropriate Federal agency to guarantee loans for such purposes.

(b) In order to encourage the commercial production of energy from geothermal resources, the head of the designated agency is authorized to, in consultation with the Secretary of the Treasury, guarantee, and to enter into commitments to guarantee, lenders against loss of principal or interest on loans made by such lenders to qualified borrowers for the purposes of—

(1) the determination and evaluation of the resource base;

(2) research and development with respect to extraction and utilization technologies;

(3) acquiring rights in geothermal resources; or

(4) development, construction, and operation of facilities for the demonstration or commercial production of energy from geothermal resources.

(c) Any guaranty under this title shall apply only to so much of the principal amount of any loan as does not exceed 75 percent of the aggregate cost of the project with respect to which the loan is made.

Terms and conditions.

(d) Loan guaranties under this title shall be on such terms and conditions as the head of the designated agency determines, except that a guaranty shall be made under this title only if—

(1) the loan bears interest at a rate not to exceed such annual per centum on the principal obligation outstanding as the head of the designated agency determines to be reasonable, taking into account the range of interest rates prevailing in the private sector for similar loans and risks by the United States;

(2) the terms of such loan require full repayment over a period not to exceed thirty years, or the useful life of any physical asset to be financed by such loan, whichever is less (as determined by the head of the designated agency);

(3) in the judgment of the head of the designated agency, the amount of the loan (when combined with amounts available to the qualified borrower from other sources) will be sufficient to carry out the project; and

(4) in the judgment of the head of the designated agency, there is reasonable assurance of repayment of the loan by the qualified borrower of the guaranteed indebtedness.

Limitation.

(e) The amount of the guaranty for any loan for a project shall not exceed $25,000,000, and the amount of the guaranty for any combination of loans for any single qualified borrower shall not exceed $50,000,000.

"Qualified borrower."

(f) As used in this title, the term "qualified borrower" means any public or private agency, institution, association, partnership,

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corporation, political subdivision, or other legal entity which (as determined by the head of the designated agency) has presented satisfactory evidence of an interest in geothermal resources and is capable of performing research or completing the development and production of energy in an acceptable manner.

PAYMENT OF INTEREST

Contract authority. 30 USC 1142.

SEC. 202. (a) With respect to any loan guaranteed pursuant to this title, the head of the designated agency is authorized to enter into a contract to pay, and to pay, the lender for and on behalf of the borrower the interest charges which become due and payable on the unpaid balance of any such loan if the head of the designated agency finds—

(1) that the borrower is unable to meet interest charges, and that it is in the public interest to permit the borrower to continue to pursue the purposes of his project, and that the probable net cost to the Federal Government in paying such interest will be less than that which would result in the event of a default; and

(2) the amount of such interest charges which the head of the designated agency is authorized to pay shall be no greater than the amount of interest which the borrower is obligated to pay under the loan agreement.

(b) In the event of any default by a qualified borrower on a guaranteed loan, the head of the designated agency is authorized to make payment in accordance with the guaranty, and the Attorney General shall take such action as may be appropriate to recover the amounts of such payments (including any payment of interest under subsection (a)) from such assets of the defaulting borrower as are associated with the project, or from any other surety included in the terms of the guaranty.

PERIOD OF GUARANTIES AND INTEREST ASSISTANCE

30 USC 1143.

SEC. 203. No loan guaranties shall be made, or interest assistance contract entered into, pursuant to this title, after the expiration of the ten-calendar-year period following the date of enactment of this Act.

GEOTHERMAL RESOURCES DEVELOPMENT FUND

Establishment. 30 USC 1144.

SEC. 204. (a) There is established in the Treasury of the United States a Geothermal Resources Development Fund, which shall be available to the head of the designated agency for carrying out the loan guaranty and interest assistance program authorized by this title, including the payment of administrative expenses incurred in connection therewith. Moneys in the fund not needed for current operations may, with the approval of the Secretary of the Treasury, be invested in bonds or other obligations of, or guaranteed by, the United States.

(b) There shall be paid into the fund the amounts appropriated pursuant to section 304(c) and such amounts as may be returned to the United States pursuant to section 202(b), and the amounts in the fund shall remain available until expended, except that after the expiration of the ten-year period established by section 203, such amounts in the fund which are not required to secure outstanding

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guaranty obligations shall be paid into the general fund of the Treasury.

Financial reports, submittal to Congress.

(c) Business-type financial reports covering the operations of the fund shall be submitted to the Congress by the head of the designated agency annually upon the completion of an appropriate accounting period.

TITLE III—GENERAL PROVISIONS

PROTECTION OF ENVIRONMENT

30 USC 1161.

SEC. 301. In the conduct of its activities, the Project and any participating public or private persons or agencies shall place particular emphasis upon the objective of assuring that the environment and the safety of persons or property are effectively protected; and the program under title I shall include such special research and development as may be necessary for the achievement of that objective.

REPORTING REQUIREMENTS

Reports to President and Congress. 30 USC 1162.

SEC. 302. (a) The Chairman of the Project shall submit to the President and the Congress full and complete annual reports of the activities of the Project, including such projections and estimates as may be necessary to evaluate the progress of the national geothermal energy research, development, and demonstration program and to provide the basis for as accurate a judgment as is possible concerning the extent to which the objectives of this Act will have been achieved by June 30, 1980.

(b) No later than one year after the termination of each demonstration project under section 105, the Chairman of the Project shall submit to the President and the Congress a final report on the activities of the Project related to each project, including his recommendations with respect to any further legislative, administrative, and other actions which should be taken in support of the objectives of this Act.

TRANSFER OF FUNCTIONS

30 USC 1163.

SEC. 303. (a) Within sixty days after the effective date of the law creating a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States (or within sixty days after the date of the enactment of this Act if the effective date of such law occurs prior to the date of the enactment of this Act), all of the research, development, and demonstration functions (including the loan guaranty program) vested in the Project under this Act, along with related records, documents, personnel, obligations, and other items to the extent necessary or appropriate, shall, in accordance with regulations prescribed by the Office of Management and Budget, be transferred to and vested in such organization or agency.

(b) Upon the establishment of a permanent Federal organization or agency having jurisdiction over the energy research and development functions of the United States, and when all research and development (and other) functions of the Project are transferred, the members of the Project may provide advice and counsel to the head of such organization or agency, in accordance with arrangements made at that time.

AUTHORIZATIONS OF APPROPRIATIONS

SEC. 304. (a) For the fiscal years ending June 30, 1976, and September 30, 1977, 1978, 1979, and 1980, only such sums may be appropriated as the Congress may hereafter authorize by law. 30 USC 1164

(b) There are authorized to be appropriated to the National Aeronautics and Space Administration not to exceed $2,500,000 for the fiscal year ending June 30, 1975, for the purpose of preparing the program definition under section 102(a).

(c) In addition to sums authorized to be appropriated by subsection (b), there are authorized to be appropriated to the fund not to exceed $50,000,000 annually, such sums to carry out the provisions of the loan guaranty program by the Project under title II.

Approved September 3, 1974.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 93-1112 (Comm. on Science and Astronautics) and No. 93-1301 (Comm. of Conference).

SENATE REPORT No. 93-849 accompanying S. 2465 (Comm. on Interior and Insular Affairs).

CONGRESSIONAL RECORD, Vol. 120 (1974):

July 10, considered and passed House.

July 11, considered and passed Senate, amended, in lieu of S. 2465.

Aug. 20, Senate agreed to conference report.

Aug. 21, House agreed to conference report.

Appendix 6
Regulations for the Geothermal Loan Guaranty Program

Title 10—Energy

CHAPTER III—ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

PART 790—GEOTHERMAL ENERGY RESEARCH, DEVELOPMENT, DEMONSTRATION AND PRODUCTION

Federal Guarantees on Loans

On October 28, 1975, the Energy Research and Development Administration (ERDA) published in the FEDERAL REGISTER (40 FR 50100) a proposed regulation concerned with enabling lenders to obtain Federal guarantees on loans to qualified borrowers for purposes related to the commercial development of practical means to produce electric power and other forms of useful energy from geothermal resources in an environmentally acceptable manner.

Generally, the proposed regulation provided priorities and criteria which ERDA intends to apply to the consideration of applications for, and granting or denial of, Federal loan guarantees. Further the regulation provided illustrations of information to be developed by the borower and the lender, and to be supplied to ERDA, including a detailed description of the project for which the and guaranty are required and an affirmation by the lender supporting the necessity for the Federal guaranty.

In addition, the regulation contained illustrations of cost items which would be acceptable for inclusion in the computation of the aggregate cost of a project.

Interested persons and Federal agencies were asked to comment and a period extending from the date of publication of the proposed regulation to December 12, 1975, was allocated for such purpose. Approximately sixty responses to the request for comments were received from the public and other Federal agencies. Generally, these comments were directed to the subject of eligible loans and priorities; definitions; loan guaranty criteria; supporting information; project costs illustrations; and, environmental considerations.

The comments, which were thoughtful and provocative, were considered thoroughly and many of them are incorporated in this final regulation. Section 790.4(b) was amended to provide a preference for small public and private utilities and small independently owned and operated businesses (as defined in §§ 790.5 (i) and (j)), and § 790.32(f) was inserted to permit the Administrator to allocate a portion of the amounts available for guarantees to such borrowers. A new section, § 790.46, was inserted to provide for future coordination between ERDA and the Department of the Interior regarding matters involving the loan guaranty program and lease administration under the Geothermal Steam Act of 1970. Another section, § 790.47, was established to provide borrowers and lenders with an ability to appeal decisions of the Manager to ERDA's Board of Contract Appeals. The requirement at § 790.20 in the proposed regulation for lenders to have available during preliminary discussions with the Manager an assessment of all aspects of the borrower's loan application was amended to provide at § 790.21(a)(23) for the submission of such information together with other information submitted with the guaranty application. In addition, a number of other changes have been made to improve clarity.

Therefore, ERDA herewith publishes this Part 790 under which it will administer its geothermal loan guaranty program. Part 790 is added to 10 CFR Ch. III to read as follows:

AUTHORITY: Sec. 105(a) of the Energy Reorganization Act of 1974, Pub. L. 93-438; Title II of the Geothermal Energy Research, Development, and Demonstration Act of 1974 Pub. L. 93-410; E.O. 11834 dated January 15, 1975.

Subpart A—General Provisions

§ 790.1 Purpose.

The purpose of this regulation is to set forth policies and procedures under which lenders may obtain a Federal guaranty on loans related to the commercial development of practicable means to produce, with environmentally acceptable processes, useful energy from geothermal resources.

§ 790.2 Objectives.

The objectives of the Federal geothermal loan guaranty program are: (a) to encourage and assist the private and public sectors to accelerate development of geothermal resources with environmentally acceptable processes by enabling the Administrator of the Energy Research and Development Administration (ERDA), in the exercise of reasonable judgment, to minimize a lender's financial risk that is associated with the introduction of new geothermal resources and technology; and, (b) to develop normal borrower-lender relationships which will in time encourage the flow of credit so as to assist in the development of geothermal resources without the need for Federal assistance.

§ 790.3 Effective date.

This regulation is effective June 25, 1976.

§ 790.4 Eligible loans and priorities.

(a) The Administrator may enter into agreements to guaranty lenders against the loss of principal and accrued interest on loans made by such lenders to qualified borrowers. Any such agreements shall be made subject to the application of priorities and preferential considerations for guarantees as set forth in paragraph (b) of this section and subject to criteria in § 790.6. Such agreements can be entered into only for the purposes of:

(1) Determination and evaluation of the commercial potential of geothermal resources;

(2) Research and development with respect to geothermal extraction and utilization technologies, including but not limited to the mitigation of adverse environmental effects;

(3) Acquisition of rights in geothermal resources; or,

(4) Development, construction, and operation of equipment or facilities for the demonstration or commercial production of energy (e.g., electric power, industrial or agricultural processes, or space heating) from geothermal resources.

(b) In complying with the objectives of the Federal geothermal loan guaranty program, the Administrator will give first priority consideration to those applications for projects having a plan of operations which show promise of quickly resulting in the development of useful energy from geothermal resources. Second priority consideration will be given to those applications for projects designed to demonstrate or utilize new technological advances or engage in the production of advanced technology components. Third priority will be given to projects that will demonstrate or exploit the commercial potential of new geothermal resource areas. The Administrator will give lower consideration to applications involving projects that initially propose geological and geophysical exploration, or the acquisition of land or leases. Within each category of priority as described herein, the Administrator will give preferential consideration to those applications in which the lender is providing a portion of the loan for which a guaranty is not requested. Additional preferential consideration within each priority category will be given to those applications involving, (1) projects from which the Federal government will receive royalty payments, and (2) projects to be carried out by small public and private utilities and small independently owned and operated businesses.

(c) A loan application which meets a lender's standard without a Federal guaranty will be regarded by the Administrator as not eligible for a loan guaranty under this regulation. No loan shall be guaranteed if the income from such loan or the income from obligations issued by the holder of such loan is excluded from gross income for the purposes of Chapter I of the Internal Revenue Code of 1954. In addition, a project which is devoted exclusively to the extraction or production of geothermal byproducts as defined in § 790.5(b), or is devoted exclusively to the desalination of geothermal brines will be regarded by the Administrator as not eligible for a Federal loan guaranty under this regulation.

§ 790.5 Definitions.

For purposes of this regulation:

(a) "Geothermal resources" means (1) all products of geothermal processes, embracing indigenous steam, geopressured fluids, hot water, and brines, (2) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations, and (3) any byproduct derived from them;

(b) "Byproduct" means any mineral or minerals or gases which are found in solution or in association with geothermal or geopressured resources and which have a value of less than 75 percent of the value of the geothermal steam and associated geothermal resources or are not, because of quantity, quality, or technical difficulties in extraction and production, of sufficient value to warrant extraction and production by themselves;

(c) "Administrator" means the Administrator of the U.S. Energy Research and Development Administration (ERDA) or a representative authorized by the Administrator;

(d) "Manager" means the Manager of ERDA's San Francisco Operations Office, 1333 Broadway, Oakland, California 94616, or a representative authorized by the Manager;

(e) "Lender" means any legal entity formed for the purpose of or engaged in the business of lending money and having the capability of servicing the loan. Examples of lenders include, but are not limited to, commercial banks, savings and loan institutions, insurance companies, factoring companies, investment banking organizations, institutional investors, partnerships, venture capital investment companies, trusts, individuals, or entities designated as trustees acting on behalf of bondholders or other lenders;

(f) "Qualified borrower" (hereinafter referred to as the borrower) means any public or private agency, institution, joint venture, limited partnership, association, cooperative, partnership, corporation, individual, political subdivision, or other legal entity having authority to enter into a loan agreement. Examples of borrowers include, but are not limited to, leaseholders, landowners, public and private electric utilities, reservoir developers, drillers, suppliers, component and equipment manufacturers, research and development firms, engineers, patent holders, and licensees;

(g) A "loan" is an obligation involving a borrower and a lender, evidenced in writing, making available to the borrower money at a specified rate of interest for a limited period of time. The loan instrument may not be capable of conversion into an equity relationship with the borrower;

(h) "Project" means an undertaking by the borrower which when completed will result in an identifiable product, system, major component or study for which a market potentially exists. Examples of a project include, but are not limited to, test and production well drilling, power plant construction, equipment manufacturing, research and development, construction of transmission lines from a geothermal power plant, and other ventures to utilize geothermal heat to serve as an energy source for nonelectric applications, such as crop drying and greenhousing;

(i) A "small public or private electric utility, including its affiliates", is, as provided in 13 CFR 121.3–10(d)(11), a business concern primarily engaged in the generation, transmission and/or distribution of electric energy for sale whose total electric output for its preceding fiscal year did not exceed four million megawatt-hours; and,

(j) A "small business, including its affiliates", is, as provided in 13 CFR 121.3–11(a), a concern which is independently owned and operated, is not dominant in its field of operation, does not have assets exceeding $9 million, does not have net worth in excess of $4 million, and does not have an average net income, after Federal income taxes, for the preceding two years in excess of $400,000 (average net income to be computed without benefit of any carryover loss).

§ 790.6 Loan guaranty criteria.

In addition to meeting the requirements for eligibility set forth in § 790.4(a), a guaranty may be made only if the following conditions are met as determined by the Administrator upon the written recommendation by the Manager:

(a) The application is signed by an authorized official of the lender and the borrower;

(b) The loan is to be made to a qualified borrower;

(c) Except as provided in § 790.43, the guaranty as to principal shall apply only to so much of the principal amount of the loan as does not exceed 75 percent of the estimated aggregate cost of the project with respect to which the loan is made. However, there is no prohibition against the guaranty being equal to 100% of the loan to be made by the lender;

(d) The lender has set forth reasons why the loan would not be made to the borrower without a Federal loan guaranty;

(e) There is satisfactory evidence demonstrating that the lender is competent to administer loan terms and conditions, and is competent to administer terms and conditions in the guaranty agreement that are applicable to the lender;

(f) When the maximum permissible guaranty is requested as provided in paragraph (c) of this section, the lender has set forth those reasons it is unwilling to undertake a loan having less than the maximum permissible guaranty so as to permit the Manager to evaluate whether the preferential consideration provided in § 790.4(b) is applicable;

(g) The loan bears interest at a rate not to exceed an annual percent on the principal obligation outstanding as the Administrator determines, in consultation with the Secretary of the Treasury, to be reasonable, taking into account the range of interest rates and lending practices prevailing in the private sector for similar loans and risks by the United States. However, it is expected that the borrower and lender will negotiate a mutually acceptable interest rate that recognises the benefits to the lender from a Federal guaranty;

(h) The terms of such loan require full repayment over a period of no more than thirty years, or no longer than the expected average useful life of any major physical asset to be financed by such loan, whichever is less, as determined by the Administrator.

(i) The amount of the loan together with other funds available to the borrower will be sufficient to carry out the project;

(j) There is reasonable assurance of payment of interest and repayment of the guaranteed portion of the loan by the qualified borrower, such as evidence that there exists or will exist a market for the project's product or results that is sufficient to enable the borrower to repay the loan;

(k) The amount of a guaranty for any loan for a project does not exceed $25,000,000;

(l) The total dollar amount of guarantees made under this regulation for any combination of outstanding loans to any single qualified borrower does not exceed $50,000,000;

(m) The project is to be performed in the United States, its territories or possessions, or on property owned or leased by the United States outside the United States, its territories or possessions;

(n) The project is technically feasible and uses environmentally acceptable processes;

(o) There is sufficient evidence, such as is provided in a plan of operations, that the borrower will initiate and complete the project in a timely and efficient manner;

(p) There is a sufficiency of encouraging geophysical, geological, hydrological and geochemical data;

(q) The borrower agrees to make available on a timely basis any technical or economic information as specified in the guaranty agreement, and, subject to provisions in § 790.33 and § 790.20(b)(ii), further agrees to the use of such information for public dissemination purposes;

(r) There is satisfactory evidence of the borrower's interest in geothermal resources;

(s) There is satisfactory evidence that the borrower is capable of completing the project in an acceptable manner;

(t) The project, whether conducted on Federal, State-owned, or private land, will be carried out with full regard to the use of environmentally acceptable processes in such a manner as to mitigate adverse environmental impact to the maximum extent practicable;

(u) The environmental risks of the project have been evaluated in accordance with § 790.23;

(v) The terms and conditions set forth in the loan agreement are acceptable to the Administrator; and,

(w) The borrower and any non-guaranteed lender agree in writing that: (1) the terms and conditions set forth in a non-guaranteed loan agreement relating to the project shall be acceptable to the Administrator, and (2) the non-guaranteed loan shall be subordinate to the guaranteed loan.

§ 790.7 Interest assistance.

With respect to any loan guaranteed pursuant to this regulation, the Manager may enter into an interest assistance contract with the borrower to pay, and to pay the lender for and on behalf of the borrower the interest charges which become due and payable on the unpaid balance of any such loan if the Manager finds:

(a) That the borrower is unable to meet interest charges, and that it is in the public interest to permit the borrower to continue to pursue the purposes of the project, and that the probable net cost to the Federal government in paying such interest will be less than that which would result in the event of a default;

(b) The amount of such interest charges which the Manager is authorized to pay is no greater than the amount of interest which the borrower is obligated to pay under the loan agreement; and

(c) The borrower agrees to repayment of interest charges paid by the Federal government including the payment of interest on such charges at an annual rate to be set by the Manager in consultation with the Department of the Treasury and stated in the interest assistance contract, and to the payment of any deferred user charge provided in § 790.31(b).

§ 790.8 Default payment.

In the event of any default by a borrower in making a payment in accordance with the loan agreement with respect to any loan guaranteed pursuant to this regulation, and except as provided in § 790.7, the Administrator will, as provided in § 790.37, authorize the Manager to make payment of principal and accrued interest in accordance with the guaranty. Thereupon, the Attorney General of the United States shall take such action as may be appropriate to recover the amounts of such payments (including any payment of interest under § 790.7) from such assets of the defaulting borrower as are associated with the project, (including patent and proprietary rights resulting from the project as provided in § 790.44) or from any other surety or security bond by or included in the terms of the guaranty. Any recovery achieved by the Attorney General which exceeds the amount paid to the lender in accordance with the guaranty agreement or interest assistance contract shall be returned to the borrower, unless the guaranty agreement provides otherwise.

§ 790.9 Period of guarantees and interest assistance.

No loan guaranty agreements will be made or interest assistance contracts entered into after September 3, 1984. Guaranty agreements in effect at that time will continue until the term of the loan is completed or until the guaranteed portion of the loan is repaid in full with accrued interest, whichever occurs first. Interest assistance contracts in effect on September 3, 1984, will remain in effect thereafter until the contract term expires or the contract is terminated in accordance with its provisions.

§ 790.10 Information for Governors.

The Administrator will, as appropriate, meet with Governors of directly affected States, regional associations of Governors, or heads of State agencies and commissions responsible for energy or environmental matters for the purpose of:

(a) Discussing the status of projects guaranteed under this regulation;

(b) Identifying means to remove or mitigate legal and regulatory barriers to the accelerated use of geothermal resources; or

(c) Evaluating plans to encourage growth in the geothermal industry.

Subpart B—Applications

§ 790.20 Filing.

(a) An application for a loan guaranty made under this regulation must be signed by the prospective borrower and lender or their authorized representatives and jointly submitted to the Manager who is responsible for processing the application. Information regarding the filing of applications may be obtained from the Manager.

(b) (1) Prior to receipt of a guaranty application, the Manager is authorized to conduct preliminary discussions with prospective lenders or borrowers wishing to obtain information or advice regarding eligibility for a loan guaranty and compliance with filing instructions, including the submission of supporting information as illustrated in § 790.21.

(2) Subject to requirements of law and this regulation, trade secrets, commercial and financial information, geological, geophysical and geographical information and data (including maps) concerning wells which the borrower makes available to ERDA during the preliminary discussion or at any other time throughout the duration of the project on a privileged or confidential basis, will be so treated by ERDA and will not be publicly disclosed without the prior written approval of the borrower. In order to assist ERDA in carrying out this provision, information deemed by the borrower or lender to fall within one of the foregoing categories shall be identified and appropriately marked by the borrower or the lender.

(c) A guaranty application may be submitted for a project that is divided into stages or milestones which are utilized as the basis for assessing the practicability of proceeding to a subsequent phase. However, in the event of failure to proceed to a subsequent phase, the Government's liability, under the guaranty agreement, will extend only to the amounts disbursed by the lender and approved by the Manager as provided in § 790.34.

§ 790.21 **Supporting information.**

(a) The lender and borrower shall provide information in support of the application such as prescribed by the Manager. The following items illustrate the range of information which may be needed, (dependent upon the type, complexity and cost of the project) so as to enable the Manager to prepare a recommendation for the Administrator's determination, as provided in § 790.6.

(1) Full description of the scape, nature, extent and location of the proposed project;

(2) A written affirmation by the lender supporting the necessity for a Federal loan guaranty;

(3) Evidence of the borrower's previous and current interest in exploiting the potential of geothermal resources;

(4) Evidence supporting the borrower's ability to complete the project;

(5) Interest rate to be charged by the lender;

(6) Period and amount of the loan and the percent of the project cost to be guaranteed;

(7) A detailed budget-type breakdown of both the estimated aggregate cost of the project and the amount to be borrowed;

(8) Evidence showing that the amount of the loan together with equity or other financing will be sufficient to carry out the project;

(9) The borrower's plan to pay interest charges and repay the loan, including assumptions regarding marketability of the project's results or product;

(10) The aggregate amount of guaranty commitments and/or guaranteed loans outstanding made to the borrower under the provisions of this regulation;

(11) Where relevant to the purpose of the loan guaranty, a copy of the borrower's title or lease agreement to the property, supported by title opinion or other locally acceptable evidence of the borrower's interest, on which the project is to be carried out;

(12) Subject to § 790.20 (b) (ii), technical information and reports, geophysical data, well logs and core data, financial statements, milestone schedules, and maps and charts;

(13) Information covering the management experience of each officer or key person in the borrower's organization who is to be associated with the project;

(14) A description of the borrower's management concept and business plan, or plan of operations, to be employed in carrying out the project;

(15) A description of the project's technical and economic feasibility;

(16) A description of the intended sources and amount of capital and its form (equity, loans from principals, loans from the lender, outside financing, or factoring) together with evidence of a commitment from these sources and a copy of each such agreement, and evidence of the financial ability of each source to honor its commitment;

(17) A copy of the loan agreement to be executed by the lender and borrower;

(18) A listing of assets associated or to be associated with the project, including appropriate data as to the useful life of any physical asset, and any other security for the loan and guaranty agreement;

(19) A description of other Federal financial assistance (e.g., direct loans, guaranteed loans, grants, contracts) available or expected to be made available to the borrower in connection with the project;

(20) A description of the processes and methods the borrower plans to utilize so as to comply with § 790.23(c);

(21) Copies of all applications when filed, and approvals when issued by Federal, State and local government agencies, for permits and authorizations to conduct operations associated with the project;

(22) A description of the borrower's organization and a copy of the business certificate, partnership agreement or corporate charter, by laws, and appropriate authorizing resolutions;

(23) The lender's written assessment of all aspects of the borrower's loan application in sufficient detail as would be completed by any prudent lender considering a loan without a guaranty, together with copies of investigations from credit bureaus, references, bank inquiries, and professional organizations;

(24) Written assurance from guaranteed and, when appropriate to the project, non-guaranteed lenders that the loan amounts as well as terms and conditions imposed by such lenders will not be altered in any significant respect without approval of the Administrator;

(25) A description of salaries (and other financial remuneration including profit sharing and stock options) to be paid to officers and employees of the borrower that are, or will be, directly associated with the project; and

(26) Evidence of consultation conducted by the borrower with appropriate agencies of any affected State regarding the proposed project.

(b) In addition to supporting information illustrated in (a) above, the Manager may independently obtain or may require the lender to include with the guaranty application the filing of information regarding the lender as deemed necessary by the Manager, including but not limited to:

(1) Description of the lender's organization and a copy of the business certificate, partnership agreement or corporate charter, by-laws, and appropriate authorizing resolutions;

(2) Copies of investigations obtained from credit bureaus, reference and bank inquiries, and professional associations;

(3) Descriptions covering the management experience of each officer or key person in the lender's organization who is or will be associated with the loan;

(4) A description of the management concept to be employed by the lender in surveillance of the loan; and

(5) When appropriate to the project, evidence of the lender's experience in surveying the financial aspects of complex technological projects.

(c) The Manager shall consider the application and other relevant information and shall be responsible for: (i) determining whether the application is in compliance with this regulation; (ii) assessing and evaluating the financial, technical, environmental, management, and marketing aspects of the project; and, (iii) recommending to the Administrator approval or nonapproval of the application. The Manager shall include with a recommendation for approval a proposed guaranty agreement containing appropriate terms and conditions pertinent to the project. The Manager will provide the borrower and lender with a written statement setting forth the basis for the Administrator's nonapproval of an application.

§ 790.22 **Project cost illustrations.**

(a) The cost elements set forth in paragraphs (b) and (c) of this section are only for the purpose of illustrating the manner by which the estimated aggregate cost of the project can be determined. It is expected that project costs will be accumulated in accordance with generally accepted accounting principles and practices which are consistently applied.

(b) Except as set forth in paragraph (c) of this section, reasonable and customary costs paid by the borrower that are directly connected to the project are generally permitted in computing the estimated aggregate project cost. These costs include, but are not limited to the following:

(1) Employees' salaries and wages, consultant fees and other outside assistance;

(2) Land purchase or lease payments, including reasonable real estate commissions;

(3) Engineering fees, surveys, plats, title insurance, recording fees and legal fees incurred in connection with land acquisition;

(4) Site improvements, site restoration and abandonment costs, access roads and fencing;

(5) Drilling of exploration wells, shallow heat-flow wells, and test, production and reinjection wells;

(6) Buildings, transmission lines, power plant equipment, and machinery;

(7) Taxes to be paid to Federal, State and local government agencies and other taxing authorities;

(8) Insurance and bonds of all types;

(9) Engineering, geological, architectural and legal fees paid in connection with drilling, machinery selection, design, acquisition and installation;

(10) Research and development necessary to complete the project;

(11) Professional services and fees necessary to obtain licenses and permits and to prepare environmental reports and data;

(12) Interest costs charged by the lender;

(13) Interest payments to other lenders;

(14) Costs incurred by the borrower prior to approval of the guaranty agree-

ment that are directly in connection with the project;

(15) Technical and socio-economic information dissemination costs;

(16) Costs to provide safety and environmental protection equipment, facilities and services;

(17) Travel and transportation costs;

(18) Bond financing costs and trustee fees;

(19) Fees for royalties and licenses;

(20) Costs associated with acquiring geophysical and other technical data;

(21) Financial and legal services costs;

(22) Costs to comply with terms and conditions specified in the guaranty agreement or required by regulations and issuances by Federal, State and local government agencies; and,

(23) A contingency reserve.

(c) Costs which are not considered as project costs and are excluded from the guaranteed portion of the loan are illustrated below:

(1) Company organizational expenses;

(2) Parent corporation general and administrative expenses and other parent corporation assessments;

(3) Dividends and profit sharing to stockholders, employees and officers;

(4) Goodwill, franchises, or trade or brand name costs;

(5) Except as provided in 790.31, fees and commissions charged to the borrower for obtaining loans and Federal assistance;

(6) Loan commitment fees charged by lenders and finders' fees;

(7) Expenses not paid or incurred by the borrower;

(8) Normal operating expenses incurred after an initial period of start-up; and,

(9) Costs that are excessive or are not directly required to carry out the project.

(d) Independently, or at the direction of the Administrator, the Manager may cause to be performed a review of any or all cost elements included by the borrower in the estimated aggregate project cost. The borrower shall make available records and other data necessary to permit the Manager to carry out such review. In carrying out this responsibility, the Manager may utilize employees of Federal agencies or may direct the borrower to submit to a review performed by an independent public accountant or other competent authority.

(e) When costs incurred prior to the approval of the guaranty agreement, as provided in paragraph (b)(14) of this section, are included in the estimated aggregate project cost, the borrower will make available to auditors selected by the Manager financial and other records necessary to complete an audit of such costs if requested by the Manager.

§ 790.23 Environmental considerations.

(a) For a proposed project being actively considered for a loan guaranty for which an environmental statement or negative determination has been prepared by a responsible Federal official, the environmental statement or negative determination and supporting assessment will be utilized by the Manager and the Administrator in considering the environmental consequences of the project.

(b) With respect to each project being considered actively for a loan guaranty for which paragraph (a) of this section is not applicable, the Manager, in accordance with 10 CFR Part 711, shall assess the potential effect of all phases of the project on the human environment, including but not limited to fish and other aquatic resources, wildlife habitat and populations, aesthetics, recreation, air and water quality, land use, and other resources in the area. This assessment will additionally consider, when appropriate to the project, the potential impact on the environment from the construction of power plants and transmission lines which may later be required but are not included in the project.

(1) To aid in the above assessment the Manager may request the views and recommendations of Federal, State, and local government agencies, environmental and industrial organizations, and others; and, when appropriate, may hold public hearings after giving due notice.

(2) If, as a result of the above assessment, the Manager determines that the proposed project will have a potentially significant effect on the quality of the human environment, final action on the guaranty application shall be held in abeyance until an environmental statement in accordance with section 102(2)(c) of the National Environmental Policy Act of 1969 has been prepared and issued by the responsible Federal official.

(3) If the Manager determines that the proposed project will not have a potentially significant effect on the quality of the human environment, a negative determination shall be prepared by the Manager and submitted, together with the assessment, to the Administrator prior to final action on the guaranty application. The negative determination together with documentation supporting that determination shall be kept on file by the Manager. Environmental assessments and negative determinations prepared in compliance with this regulation shall be placed in ERDA Public Document Rooms.

(c) Each loan guaranty agreement shall include the following general terms and conditions for the protection of the environment:

(1) the borrower shall comply with all applicable Federal, State and local requirements with respect to the control of air, land, water, and noise pollution. In the absence of requirements, the Manager, after consultation with appropriate Federal, State, and local government agencies, may recommend requirements for the Administrator's consideration and the borrower shall comply with such requirements as are approved by the Administrator.

(2) The borrower, in addition to any other action required by Federal, State or local requirements, or requirements established by the Administrator, or conditions set forth in leases issued by an agency of the Federal government, shall take the following specific actions: (For purposes of this paragraph the appropriate agency official means the Manager for projects conducted on private or State-owned land, and the Head of a Federal agency for projects conducted on any land administered by any agency of the Federal government.)

(i) Conduct operations in such a manner as to minimize disturbance to vegetation, drainage channels and streambanks, and employ such soil and resource conservation and protection measures as are deemed necessary by the appropriate agency official;

(ii) Remove or dispose of all waste generated in connection with the project in a manner acceptable to the appropriate agency official;

(iii) Take all reasonable precautions necessary to minimize to the maximum extent practicable land subsidence or seismic activity which could result from the project, including the taking of measures to monitor operations for land subsidence and seismic activity and, when requested by the appropriate agency official, make available records of all monitoring activities;

(iv) Take aesthetics into account in the planning, design, and construction of facilities;

(v) Employ such measures as are deemed necessary by the appropriate agency official to protect fish and wildlife and their habitat;

(vi) Conduct activities on known or suspected archeological; paleontological, or historical sites in accordance with specific instructions issued by the appropriate agency official;

(vii) Provide, in a timely manner, for the reasonable restoration of all disturbed lands, including the plugging of abandoned wells; and promptly employ corrective measures whenever adverse environmental effects exceed those expected; and,

(viii) Employ such other measures as are deemed necessary by the appropriate agency official to protect the quality of the human environment.

(d) For projects conducted on private or State-owned land:

(1) Assuring compliance with the requirements set forth in paragraph (b) of this section shall be the responsibility of the Manager, who may utilize experts from Federal agencies, National Laboratories or private firms, and shall have access to reports prepared by the borrower in compliance with requirements imposed by Federal, State and local government agencies.

(2) The borrower shall submit an annual report to the lender and the Manager giving a full account of actions taken to comply with the requirements set forth in paragraph (c) of this section.

(e) For projects to be conducted on any land administered by an agency of the Federal government:

(1) Assuring compliance with safety and operating procedures and environmental protection requirements shall be the responsibility of the appropriate Federal agency or a representative authorized by the Head of that agency.

(2) The borrower shall provide to the lender and the Manager a copy of each annual environmental compliance report prepared by the borrower in accordance with regulations issued by the appropriate Federal agency.

(f) Nothing in this regulation shall be construed to modify requirements imposed on the borrower or lender by Federal, State and local government agencies in connection with permits, licenses, or other authorization to conduct or finance geothermal activities.

§ 790.24 Mandatory purchase of flood insurance.

The Flood Disaster Protection Act of 1973 (Pub. L. 92-234) may require purchase by the borrower of flood insurance as a condition of receiving a guaranty on loans for acquisition or construction purposes in an identified flood plain area having special flood hazards. Questions emanating from borrowers or lenders regarding compliance with provisions of the Flood Disaster Protection Act and guidelines of the Federal Insurance Administration will be referred to the Manager. When the purchase of flood insurance is required, as finally determined by the Manager, such costs can be included by the borrower in the estimated aggregate project cost.

Subpart C—Servicing and Closing

§ 790.30 Loan servicing by lender.

Loan guaranty agreements approved in accordance with this regulation shall provide that:

(a) The lender shall exercise such care and diligence in the disbursement, servicing, and collection of the loan as would be exercised by a reasonable and prudent lender in dealing with a loan without guaranty;

(b) The loan agreement shall provide the customary period of grace for the making of any payment of principal or interest. However, the lender shall not grant to the borrower any further extension of time over and above any period of grace for the making of any payment in whole or in part under the loan agreement without the prior written consent of the Manager;

(c) The lender shall notify the Manager in writing without delay:

(1) That the first disbursement is ready to be made, together with evidence from the borrower that the project has commenced or is about to commence;

(2) Monthly, or at other agreed upon intervals, of the date and amount of each subsequent disbursement under the loan;

(3) Of any non-payment by the borrower of principal or interest as required by the loan agreement, if such non-payment is not cured within the grace period, together with evidence of appropriate notifications made by the lender to the borrower;

(4) Of any failure, known to the lender, by an intended source of capital to honor its commitment;

(5) Of any failure by the borrower, known to the lender, to comply with terms and conditions as set forth in the loan agreement or guaranty agreement; or,

(6) When the lender believes that the borrower may not be able to meet any future scheduled payment of principal or interest.

(d) In the event the lender retains the option to accelerate payment of the borrower's indebtedness, the lender shall not do so without the prior written consent of the Manager.

(e) If the guaranty agreement so provides, the loan agreement will permit the borrower to defer payments of principal until such time that income from the project is sufficient to meet this obligation.

(f) Lenders will submit to the Manager periodic financial statements that report the status and condition of each loan guaranteed under this regulation. The Manager will prescribe the frequency, format and content of such statements. However, a report on each loan guaranty agreement entered into under this regulation shall, as a minimum, be submitted to the Manager annually on the anniversary date of the guaranty agreement. Reports will be furnished to the Manager until such time as the guaranteed portion of the loan or interest assistance is repaid.

§ 790.31 User charge.

(a) A user charge will be collected annually from the lender imposed on the guaranteed portion of the loan and computed at a rate to be set forth in the guaranty agreement. The rate shall be imposed on the anticipated average amount of the guaranteed portion of the loan that is estimated to be outstanding during the year. The user charge may be passed to the borrower by the lender and in such instances may be included in the project cost.

(b) At the time the guaranty agreement is closed, as set forth in § 790.45(d), the lender shall present to the Manager payment of the first year's user charge. Subsequent payments of the charge will be made by the lender on the anniversary date of closing. If interest assistance is in effect, payments of this charge, if passed by the lender to the borrower, will be deferred for the term of the interest assistance contract.

(c) The Administrator annually will evaluate whether the user charge rate being imposed is sufficient to cover anticipated administrative, default and interest assistance costs and, when appropriate, establish a revised rate to be applied to new guaranty agreements.

§ 790.32 Geothermal Resources Development Fund.

(a) As provided in Sec. 204(a) of Pub. L. 93-410, there is established in the Treasury of the United States a Geothermal Resources Development Fund (hereinafter referred to as the Fund), which is available to the Administrator in carrying out the loan guaranty and interest assistance program contemplated by this regulation, including the payment of administrative expenses incurred in connection therewith.

(b) Appropriations to the Fund that are made available through legislation, or repayments made by borrowers in accordance with terms and conditions in interest assistance contracts, or amounts returned to the United States through recoveries by the U.S. Attorney General, as provided in § 790.8, and not disbursed in accordance therewith, shall, except as otherwise provided by law, be available to the Administrator for the payment to lenders of principal and interest on guaranty agreements and interest assistance contracts made in accordance with this regulation. In addition, balances in the Fund may be used for necessary administrative expenses incurred by ERDA or other Federal agencies acting pursuant to ERDA direction in carrying out the provisions of this regulation.

(c) In the event of a default, the Manager may enter into contracts as required to preserve the collateral for the loan and to complete unfulfilled environmental requirements. The cost of such contracts may be charged to the Fund.

(d) In the event that interest assistance payments and default payments exhaust balances in the Fund, the Administrator will promptly seek to obtain appropriations as are authorized.

(e) Moneys in the Fund not needed for current operations may, with the approval of the Secretary of the Treasury, be invested in bonds or other obligations of, or guarantees by, the United States.

(f) Not less than ten percent of the amount available for loan guarantees during a fiscal year will be allocated to guarantees on loans to small public and private utilities and small independently owned and operated businesses, as defined in § 790.5. The Administrator, at his discretion, may adjust the allocation reserved for small concerns. To the extent that guarantees on loans to qualified small concerns are not issued within six months following the beginning of each fiscal year, the uncommitted allocation of loan guarantees for small concerns, at the discretion of the Administrator, may become available on an unrestricted basis.

§ 790.33 Project monitoring.

The guaranty agreement shall provide that employees and representatives of ERDA shall, with the Manager's approval, have access to the project site. The lender, to the extent lawful and within its control, and borrower will assure availability of information related to the project as is necessary to permit the Manager to determine technical progress, soundness of financial condition, management stability, compliance with environmental protection requirements, and other matters pertinent to the guaranty.

§ 790.34 Loan disbursements by lender.

Unless otherwise provided in the guaranty agreement, the lender shall not make any disbursement on the loan until:

(a) It has followed notification requirements as set forth in § 790.30(c)(1) and (2) and has received written notice from the Manager that disbursement is approved; and,

(b) It has received from the borrower satisfactory documentary evidence, as provided in § 790.35, that funds requested will be used to pay the borrower's costs incurred or to be incurred for the project.

§ 790.35 Satisfactory documentary evidence.

The borrower shall furnish to the lender a written statement in support of each request by the borrower for loan disbursements, setting forth in such detail as the lender or Manager may require the purposes for which disbursement is requested and an attestation that such disbursements will be used only for such purposes. Signature on the requesting document shall be made by a person authorized to order the expenditure of the borrower's funds.

§ 790.36 Withdrawal of guaranty.

(a) The Administrator, may, upon the written recommendation of the Manager, terminate the guaranty by written notice to the lender and the borrower if the Manager finds that:

(1) Initiation of activity on the project has not occurred within the period of time set forth in the guaranty agreement. Within sixty days after termination under this circumstance, the Manager shall reimburse to the lender the full amount of the user charge paid by the lender if the charge has not been passed to the borrower;

(2) There is non-compliance on the part of the borrower or the lender with material terms and conditions set forth in either the loan agreement or the guaranty agreement, other than those concerning initiation of activity as referred to in paragraph (a)(1) of this section; or,

(3) There is failure by the borrower to acquire capital from intended sources, as provided in § 790.21(a)(16), and the borrower is unable to acquire alternate sources within a reasonable time as may be approved by the Manager.

(b) If the borrower fails to acquire capital from intended or alternate sources, or fails to comply with material terms and conditions set forth in the loan or guaranty agreement, the Manager shall notify the borrower and the lender that the guaranty may be reduced to the amount that has been disbursed by the lender as of the date of the notice. Disbursements made by the lender after such notification is received will not be covered by a guaranty.

(c) If the lender fails to comply with any material term or condition set forth in the guaranty or loan agreement, the guaranty may be terminated. Notice of the Manager's finding that a material term has not been complied with shall be served by the Manager upon the borrower and the lender. Following notification, the borrower will be allowed reasonable time to acquire a substitute lender that is capable of complying with provisions in this regulation. If the borrower obtains a substitute lender satisfactory to the Administrator, a new guaranty agreement will be negotiated. Upon issuance of the new guaranty to the substitute lender, the original lender shall be reimbursed by the borrower for unpaid principal outstanding and accrued interest.

§ 790.37 Default and demand.

(a) If the borrower defaults in making payment of principal or interest within the time period allowed in § 790.30(c)(3) and the lender has complied with the requirements placed on it as set forth in §§ 790.30 and 790.34, the lender may make demand in writing upon the Manager for payment pursuant to the guaranty, subject to the conditions described in paragraphs (b), (c) and (d) of this section.

(b) The Manager shall, pursuant to the provisions of § 790.7, determine whether an interest assistance contract shall be executed. In the event that interest assistance is not warranted, the Manager shall so notify the Administrator and the lender. The lender shall make available without delay such documents and certifications as the Manager may reasonably require evidencing the lender's compliance with notification provisions of the guaranty agreement.

(c) Upon default by the borrower and notification by the lender, and to the extent that sufficient reserves exist in the Geothermal Resources Development Fund: (i) upon approval of the Administrator, the Manager shall, within sixty days after receipt of such documents, pay to the lender on a proportionate basis or in full, whichever the guaranty agreement provides, the guaranteed amount of unpaid principal and accrued interest outstanding at the date of default; and (ii) during the period beginning from receipt of such documents and until payment is made by the Manager, interest payable by the United States will accrue on the guaranteed debt at a rate to be determined by the Secretary of the Treasury taking into consideration current average market yields on outstanding short-term Treasury securities.

(d) The lender shall, concurrently with payment in full of all amounts guaranteed by the United States, assign to the United States and transfer and deliver to the Manager the loan documents, together with all collateral documents evidencing any and all security for and guarantees of the loan then held by the lender as set forth in the loan or guaranty agreement.

§ 790.38 Preservation of collateral.

Upon default by the borrower, the holder of collateral associated with the project shall take actions such as the Manager may reasonably require to provide for the care, preservation, and maintenance of such collateral so as to achieve maximum recovery upon liquidation of c collateral, security and guarantees for the loan. Except as provided in §§ 790.37 and 790.40, the lender shall not waive or relinquish, without the consent of the Manager, any collateral or guaranty for the loan to which the Government would be subrogated upon payment under the guaranty agreement to the lender.

§ 790.39 Treatment of payments.

When the lender holds a guaranteed and non-guaranteed portion of a loan, payments of principal made by the borrower in accordance with the loan agreement shall be applied by the lender to reduce the guaranteed and non-guaranteed portions of the loan on a proportionate basis.

§ 790.40 Assignment and incontestability.

(a) Except as may be required by law, the lender may assign to another lender rights and obligations under the loan or guaranty agreement only with the prior written consent of the Administrator.

(b) The lender may provide other lenders with participating shares in the loan without the prior consent of the Administrator. Written notice shall be given by the lender to the Manager and the borrower when participating shares are so provided. However, the original lender shall continue to be responsible for and perform the provisions of the guaranty agreement pertaining to the lender, unless the Administrator approves a substitute lender.

(c) The guaranty agreement shall be conclusive evidence that the guaranty and the underlying loan are in compliance with the provisions of Pub. L. 93-410 and this regulation, and that such loan has been approved and is legal as to principal and interest and other terms. Such a guaranty shall be valid and incontestable by the Government, except for fraud or misrepresentation by the holder of the obligation.

§ 790.41 Survival of guaranty agreement.

The guaranty agreement shall be binding upon the lender, the borrower and the Administrator and upon their successors and assigns and shall survive payment by the United States. No delay or failure of the Administrator or the Manager in the exercise of any right or remedy and no single or partial exercise of any such right or remedy shall preclude any further exercise thereof; and no action taken or omitted by the Administrator or the Manager shall be deemed a waiver of any such right or remedy.

§ 790.42 Security with respect to borrower's assets.

Each loan guaranteed under this regulation will be secured by liens or assignments of rights in assets associated with the project, or such other security specified in the guaranty agreement as may be reasonably required to protect the interests of the United States. Upon default by the borrower, as set forth in § 790.8, the Attorney General will seek recovery from the assets of the borrower that are associated with the project or specified in the guaranty agreement.

§ 790.43 Other Federal assistance.

(a) Nothing in this regulation shall be interpreted to deny or limit the borrower's right to seek and obtain other Federal financial assistance (e.g., contracts, grants, direct loans or guaranteed loans). However, the total amount of Federal financial assistance, including guarantees made under this regulation, obtained by the borrower for the project, shall not exceed 75 percent of the estimated aggregate cost of the project to be undertaken by the borrower.

(b) After closing of the loan guaranty agreement, the borrower will not undertake any work in connection with the project (by contract or grant) for a Federal agency without the Manager's written finding that performance of the work will not adversely affect the borrower's ability to comply with pertinent terms and conditions in the loan and guaranty agreement.

§ 790.44 Patent and proprietary rights.

(a) Patents and other proprietary rights accruing to the borrower and resulting from the project will remain with the borrower, except as such rights shall be, in the case of default, treated as project assets in accordance with terms and conditions in the guaranty agreement.

(b) The guaranty agreement may provide that patents or other proprietary intellectual property rights utilized in or resulting from the project, which are owned or controlled by the borrower, shall be made available to other domestic parties upon reasonable terms and conditions which protect the confidentiality of information, if such action is determined by the Administrator to be in the public interest. This requirement will not be needed where the principal purpose of the loan to be guaranteed is to utilize generally available technology to determine and evaluate a new geothermal resource base, or the acquisition of rights in geothermal resources.

(c) Where the principal purpose of the loan is for research and development with respect to extraction and utilization technologies, or for the development or demonstration of new and unique facilities or equipment, the requirements for making patents and other proprietary intellectual property available to other domestic parties shall normally be included in the guaranty agreement unless the Administrator determines, upon the recommendation of the Manager, that such implementation would either seriously impair the borrower's ability to conduct the project, seriously impair the borrower's ability to maintain a marketplace posture, or be inconsistent with the borrower's pre-existing contractual obligations. The Administrator's determination on this matter shall include consideration of whether attainment of the objectives of the geothermal loan guaranty program, as set forth in § 790.2, will be adversely affected by this requirement.

§ 790.45 Closing.

The major activities leading to the closing of the guaranty agreement include the following:

(a) When an application for a loan guaranty has been approved by the Administrator, the Manager will so notify the lender and the borrower and provide them with a copy of the proposed guaranty agreement.

(b) A preclosing conference will be arranged by the Manager, if the lender or borrower requests one, to discuss the terms and conditions contained in the guaranty agreement.

(c) Requests by the lender or borrower for modification of the terms and conditions set forth in the guaranty agreement shall be submitted to the Manager, supported by such documentation and facts as would justify the requests.

(d) Immediately after agreement to terms and conditions, the Manager shall arrange with the lender and the borrower for the preparation and review of necessary documents and agree upon a date for execution of the guaranty agreement and payment of the user charge.

§ 790.46 Suspension, termination or cancellation of operations or production on federal land administered by the Secretary of the Interior.

(a) The Manager shall inform the Supervisor (as defined in 30 CFR 270.2(c)) when a loan guaranty is approved involving a Federal lease, so as to provide for future coordination of the loan guaranty program and lease administration.

(b) Under regulations issued by the Department of Interior, a leaseholder may, as provided in 43 CFR 3205.3–8 and 30 CFR 270.17, apply for suspension of operations or production, or both, under a producing geothermal lease (or for relief from any drilling or producing requirements of such a lease). When a loan guaranty has been issued under this regulation for a project to be conducted by a qualified borrower who is a lessee under the above cited regulation, the borrower shall submit the suspension application to the Manager, together with a statement setting forth complete information showing the effect of such suspension on the borrower's ability to comply with terms and conditions set forth in the loan agreement. The Manager will notify the borrower in those situations when approval of the application might cause default by the borrower. Except in cases where potential environmental safety or reservoir damage is imminent, the borrower shall obtain the Manager's approval prior to submitting a suspension application to the Supervisor.

(c) 43 CFR 3204.3 requires that each geothermal lease issued by the Department of the Interior provide for the readjustment of terms and conditions at not less than 10-year intervals beginning 10 years after the date geothermal steam is produced. When a guaranty under this regulation has been issued for a loan on a project to be conducted by a borrower who is a lessee, and the borrower files an objection to any proposed readjustment with the Authorized Officer (as defined in 43 CFR 3000.0–5(f)) a copy of the objection shall be submitted without delay by the borrower to the Manager. The Manager shall forward a copy of the objection to those lenders concerned, and shall consult with the Authorized Officer regarding any final action by the Authorized Officer which might terminate the lease. The Manager shall prepare an assessment on the effect of the proposed readjustment of lease terms and conditions that would substantially limit the borrower's ability to comply with the terms and conditions set forth in the loan agreement. The Manager shall forward his assessment in writing to the Administrator, the Authorized Officer and the Supervisor.

(d) Upon receipt by the lessee of notice of a proposed cancellation of a lease by the Authorized Officer, the lessee with a loan guaranteed under this regulation will provide the Manager and the lender with notice of such proposed action. Upon receipt of such notice the Manager will consult with the Supervisor and Authorized Officer for the purpose of determining whether the public interest can best be served by an acceptable alternative arrangement, such as obtaining assignments for a party qualified to hold geothermal leases who is a qualified borrower and who is willing to assume the original lessee's loan agreement and related undertaking, so that operation and production can continue.

(e) If default is likely to occur as a result of termination or cancellation of a lease, the Manager shall request the Supervisor or the Authorized Officer to rescind the lessee's privilege of removing assets from the premises, as provided in 43 CFR 3244.5.

§ 790.47 Appeals.

All decisions by the Manager relating to disputes arising under a guaranty agreement or loan agreement made under and entered into pursuant to this regulation shall be in writing. The borrower or lender, as applicable, may request the Manager to reconsider any such decision. If not satisfied with the final decision made by the Manager, the borrower or lender, upon receipt of such written decision, may appeal the decision within 30 days, in writing, to the Chairman, Board of Contract Appeals (EBCA), Energy Research and Development Administration, Washington, D.C. 20545. That Board when functioning to resolve such loan guaranty disputes, shall proceed in the same general manner as when it presides over appeals involving contract disputes. The decision of the Board with respect to such appeals shall be the final decision of the Agency.

Signed at Washington, D.C., this 25th day of May, 1976.

ROBERT C. SEAMANS, JR.,
Administrator.

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